ACHIEVEMENT OF NINTH-GRADE STUDENTS IN SCIENCE CURRICULA EMPHASIZING CONCRETE AND FORMAL REASONING

by

W. Barry Miller

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The author wishes to dedicate this study to Dr. William M. Alexander, Professor Emeritus of the University of Florida. The standard of excellence of his work in contributing to the improvement of early adolescent education and his encouragement and support over the past seven years have been inspirational. It was directly due to the advice and guidance of Dr. Alexander that the author attended the Graduate School of the University of Florida.

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W. Barry Miller

December 1980

Chairman: Dr. Gordon Lawrence

Major Department: Curriculum and Instruction

The two major purposes of the study were to determine the cognitive development levels of a group of ninth-grade students, and to investigate differences between the scholastic test scores of concrete and formal operational students on predetermined curriculum units in science education, one of which emphasized concrete operational reasoning and the other, formal operational reasoning.

The investigation took place in New Brunswick, Canada, during the 1978-1979 school year. The sample included 133 ninth-grade students, the total ninth-grade population, from a selected junior high school. The total sample included 61 males and 72 females.

Scores from a test developed by the Cognitive Analysis Project for the National Science Foundation and the Group Embedded Figures Test determined the cognitive developmental level of students.

Students were divided into two groups. The Experimental Group was assigned a concrete operational curriculum unit and the Comparison Group was assigned a formal operational curriculum unit. Each group included a representative number of students who may be identified as concrete, transitional, and formal operational in their pattern of reasoning. The transitional and formal operational categories were combined due to the small number of formal operational students.

The major findings of the study include the following:

1. Concrete operational students in the Experimental Group achieved higher test scores on a curriculum unit assessed as being concrete operational than did students of a similar conceptual level in the Comparison Group who were tested on a curriculum unit assessed as being formal operational.

2. Transitional and formal operational students in the Experimental Group achieved higher test scores on a curriculum unit assessed as being concrete operational than did students of a similar conceptual level in the

Comparison Group who were tested on a curriculum unit assessed as being formal operational.

3. Students of the Experimental Group attained higher test scores on the curriculum unit assessed as being concrete operational than on either of three previous curriculum units. The three previous curriculum units were from the prescribed text assessed as being formal operational.

4. Students of the Comparison Group attained higher test scores on three previous curriculum units than on the curriculum unit assessed as being formal operational. The three previous curriculum units were from the prescribed text assessed as being formal operational.

5. There was no significant relationship between sex and cognitive level.

The ninth-grade sample investigated showed 63.2 percent of the students at the concrete operational level; 35.3 percent were transitional; and 1.5 percent were formal operational. These findings are congruent with the findings of earlier studies which had concluded that few students in senior high school are at a formal operational level of cognitive development. The curriculum unit designated as being formal operational was less suitable in terms of the intellectual level of the students in this study than the concrete curriculum unit.

It was recommended that teachers be provided meaningful experiences and opportunities to observe children in an effort to analyze levels of reasoning, to analyze textual materials in terms of cognitive level, to practice translating abstract material to concrete experiences, and to practice in administering individual Piagetian tasks and the instruments used in this study.

A need was expressed for replications of this study and for other practical classroom-based research focusing on early adolescents in all subjects of curriculum.

CHAPTER 1

INTRODUCTION

A major thrust of the curriculum movement of the 1960's was to construct new science and social science curricula at the elementary and secondary levels.

It is commonplace for many of these curricula to suffer from too great an emphasis upon the conceptual content of the lessons and too little concern with the logical structures of the tasks the child is being set. Evidence is accumulating which suggests that the curricula wrongly presuppose students' ability to reason at an abstract or formal operational level.

Piaget's theory clearly predicts that concrete operational students will not be able to understand concepts that require the building of theories and departures from concrete reality, whereas formal operational students will be able to understand both concrete and abstract concepts.[1]

According to the Piagetian model, formal thought begins to develop at age 11 or 12 and reaches an equilibrium state at around age 15 or 16. It is interesting to note, however, that at least one British[2] and several American[3] studies have indicated that Piaget's norms for the achievement of formal operations probably are not valid for British and American populations.[4]

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[1] Bärbel Inhelder and Jean Piaget, The Growth of Logical Thinking from Childhood to Adolescence: An Essay on the Construction of Formal Operational Structures, trans. Anne Parsons and S. Seagrin (New York: Basic Books, 1958), pp. 339-342.

In each of these studies, the age suggested by Piaget has proved to be too low, and many individuals have failed to reach the formal level at any age, at least as measured by various researchers. Karplus and Karplus,[5] for example, report that formal thinking was used by only 15 percent of college preparatory students in grades 10 through 12 and that the percentage was no higher in a sample of adults; and McKinnon and Renner, using different tests, found that "almost 75 percent" of their sample of entering college freshmen "were either partially or completely concrete operational in their thinking"--that only about one-fourth of them thought consistently in a way that could be classified with any degree of confidence as "formal."[6]

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[2] K. Lovell and I. B. Butterworth, "Abilities Underlying the Understanding of Proportionality," Mathematics Teaching, Vol. 37, 1966, 5-9.

[3] E. D. Dulit, "Adolescent Thinking à la Piaget--The Formal Stage," Journal of Youth and Adolescence, Vol. 1, 1972, 281-301; Elizabeth F. Friot, "The Relationship Between the Inquiry Teaching Approach and Intellectual Development," (PhD dissertation, University of Oklahoma, 1970), p. 402; Elizabeth F. Karplus and Robert Karplus, "Intellectual Development Beyond Elementary School. I. Deductive Logic," School Science and Mathematics, December 1970, pp. 398-406; Robert Karplus and Rita W. Peterson, "Intellectual Development Beyond Elementary School. II. Ratio--A Survey," School Science and Mathematics, December 1970, pp. 813-820; Joseph W. McKinnon and John W. Renner, "Are Colleges Concerned with Intellectual Development?" American Journal of Physics, Vol. 39, 1971, 1047-1052; Robert J. Ross, "Some Empirical Parameters of Formal Thinking," Journal of Youth and Adolescence, Vol. 2, 1973, 167-177.

[4] Jean Piaget in "Intellectual Evaluation from Adolescence to Adulthood," Human Development, Vol. 15, 1972, 6, states that his subjects were "from the better schools of Geneva."

Pierre R. Dasen in "Cross-cultural Piagetian Research--A Summary," Journal of Cross-cultural Psychology, Vol. 3, 1972, 23-29, reports that the British and American deviation from Piaget's norms is small compared to those of non-industrialized societies or even to those of the lower socio-economic classes in Western countries.

[5] Karplus and Karplus, "Intellectual Development Beyond the Elementary School. I. Deductive Logic," pp. 398-406.

Statement of the Problem

If the Piagetian model is correct in contending that concrete thinkers cannot understand abstract subject matter that has no basis in their concrete experience, and if, indeed, a large portion of secondary school students are concrete operational thinkers, then a major portion of today's secondary school science curricula is beyond the student's level of understanding and is, therefore, inappropriate. This conclusion is one Kohlberg and Gilligan[7] came to when they stated: "Clearly these new curricula assumed formal operational thought rather than attempting to develop it."

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[6] McKinnon and Renner, "Are Colleges Concerned with Intellectual Development?" pp. 1047-1052.

[7] L. Kohlberg and C. Gilligan, "The Adolescent as Philosopher: The Discovery of the Self in a Post Conventional World," Daedalus, Vol. 100, 1971, 1082.

Elkind[8] stated that it is the discrepancy between curriculum and students' levels of operation which causes mismatch and results in the curriculum-disabled child.

One of the fundamental educational needs is basic research at the classroom level on how learners of all developmental stages deal with curricular material, and how well they learn concepts at levels of abstraction that are theoretically matched or mismatched to their stages of development. This study is one effort in response to that research problem.

The purpose of this study was to gather evidence to answer five questions.

1. Are ninth-grade students assessed in this study predominantly at the concrete, transitional or formal operational stage of intellectual development? Do they differ in this regard according to sex?

2. Are the percentages of ninth-grade students assessed in this study at the concrete, transitional and formal operational stages consistent with earlier studies?

3. Is there evidence of a discrepancy between the conceptual level required by the prescribed curriculum and the students' levels of operational thought?

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[8] David Elkind, Piaget's Theory of Cognitive Development: Interpretation of Its Effect on Curriculum, Presentation at the University of Florida, 1978.

4. When concrete operational students use textual material judged as requiring concrete operational thought, will they have higher scholastic test scores than students of a similar conceptual level who use textual material judged as requiring formal operational reasoning?

5. When transitional and formal operational students use textual material judged as requiring formal operational thought, will they have comparable scholastic test scores to students of similar conceptual levels who use textual material judged as requiring concrete operational reasoning?

Delimitations

The study conducted includes a concise description of the thoughts and work of Piaget through an understanding taken primarily from secondary sources. Curriculum units selected for classroom instruction were reviewed and analyzed by a panel of experts in the field of Piagetian studies relative to science education. The concepts presented in each of the units were categorized by panel members as requiring either concrete or formal operational reasoning. One unit of study was described as containing more concrete operational concepts while the other was identified as being predominantly formal operational. This method of warranting the treatment variables, although probably not as credible as an evaluation instrument, assuming one could be found, did prove informative as noted experts commented on the same instructional materials, and did differentiate between the two sets of textual materials.

The study focused on the total ninth-grade population of one junior high school. Any interpretation of the data should reflect this limitation.

The transitional and formal operational categories were combined due to the almost total absence of formal operational students (only two students were assessed to be formal operational).

Assumptions

Piaget has concerned himself primarily with the general psychological processes in cognitive development. He has not directly concerned himself with the topic of individual differences, though the fact that differences between individuals do exist is implicit in all his work. "The major factor in cognitive development is the interaction of maturation, experience, social interactions, and equilibration."[9] Different individuals can be expected to differ with respect to each of these variables.

Children can be expected to differ in their histories of maturation, experience, social interaction, and equilibration, and they can differ in how these factors interact to govern cognitive development. The implication is that wide individual differences in conceptual development can be expected in children. It was assumed that such factors, which might have an effect on the learning process and test results, were distributed among the sub-groups of the population studied.

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[9] Barry J. Wadsworth, Piaget's Theory of Cognitive Development (New York: David McKay Company, Inc., 1975), p. 122.

Whereas Piaget has not differentiated between oral and written language when discussing the relationships between language and reasoning ability, it was assumed that language is dominated by thought or reasoning. In this study, it was assumed that an analysis of written language from an individual, as in Renner's instrument used in the study, may give an indication of that individual's reasoning ability or the level of cognitive development comparable to that identified through oral communication.

Definition of Terms

Accommodation: Accommodation is the aspect of cognitive activity that involves the modification of mental structures (or sensorimotor schemes) to correspond with objects in reality.

Assimilation: Assimilation is the aspect of cognitive activity that involves the incorporating of new objects and experiences into a structure in the mind (or into a sensorimotor scheme).

CAP Incidents: The Cognitive Analysis Project was conducted under a grant from the National Science Foundation for the purpose of developing written material that teachers could use with large groups to identify, in Piagetian terms, the intellectual development stage of each member of the group simultaneously. Previous to this project such measurement could be obtained only through a one-to-one Piagetian task interview. The CAP Incidents, developed by the Cognitive Analysis Project, are problems which require written solutions by students. The reading level was controlled through computer analysis under the direction of Dr. Milton D. Jacobson, University of Virginia. Both the Harris-Jacobson Scale and the Dale-Chall Formula for predicting readability were used. The identification of students' cognitive levels by the CAP Incidents correlated highly with the identification made by one-to-one entire individual Piagetian task interviews. After analysis and scoring, CAP Incidents identify a student's level or stage of cognitive development as concrete, transitional or formal operational.[10]

Concrete operations: Concrete operations are the internal manipulations of objects that are (or have been) perceived; thinking that is dependent on the concrete, real world.

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[10] John W. Renner, Evaluating Intellectual Development Using Written Responses to Selected Science Problems, a Report to the National Science Foundation on Grant Number EPP 75-19596, "Analysis of Cognitive Process," 1977.

Early adolescence: Early adolescence is the stage of growth and development attained by most youth between their twelfth and fifteenth year of life. It is during this critical period of rapid change that the junior high school and/or middle school discharges its responsibilities to youth.

Equilibration: Equilibration is the active process by which people respond to disturbances in their ordinary way of thinking through a system of compensations; the result is new understanding and satisfaction, i.e., equilibrium.

Equilibrium: Equilibrium is the state of balance, satisfaction, or understanding.

Formal operations: Formal operations are the internal manipulation of concepts, relations, and propositions; thinking that can concern itself with the possible rather than simply the real, the form of a statement as distinct from its content, the abstract rather than the concrete.

GEFT: The Group Embedded Figures Test, when used with selected CAP Incidents, was found to improve the correlation of the Incidents to the Entire Individual Piagetian task-interview. This test is said to discriminate between field dependent and field independent thinkers.[11] This discriminatory skill appears necessary to success on separation and control of variables in the Piagetian task-interview.[12]

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[11] Herman A. Witkin, Philip K. Oltman, Evelyn Raskin, and Stephen A. Kamp, A Manual for the Embedded

Intelligence: Intelligence, in the broad sense, is the totality of possible coordinations that structure the behaviour of an organizm. Intelligence considered as a totality characterizes a given stage and is derived from the actual coordinations of a previous stage through formal reflecting abstraction. In a narrower sense, it is limited to operational intelligence, including sometimes the later phases of the sensorimotor stage.

Preadolescence: Preadolescence is the stage of growth and development marked by the conflict between the child's sense of industry and his sense of inferiority. The 10 to 12 year old gains his sense of identity through his perceptions of what he can do.[13]

Scheme: A scheme is a well defined sequence of sensorimotor activity, which can be generalized to similar situations.

Structure: Structure refers to an ordered, interrelated system of knowledge or operations.

Figures Test (Palo Alto, California: Consulting Psychologists Press, 1971).

[12] Renner, op. cit.

[13] Erik Erikson, Identity: Youth and Crisis (New York: W. W. Norton & Co. Inc., 1968), p. 177.

Hypotheses

This study had two major purposes: to determine the Piagetian cognitive level of ninth-grade students, and to investigate differences between the cognitive development levels of the students and their scholastic test scores on predetermined curriculum units in science education. These purposes formed the basis for testing the following null hypotheses:

1. There is no significant difference between scholastic test scores of concrete operational students of Comparison and Experimental Groups on assigned curriculum work.

2. There is no significant difference between scholastic test scores of transitional and formal operational students of Comparison and Experimental Groups on assigned curriculum units.

3. There is no significant difference between scholastic test scores from previous curriculum units for Experimental Group Students and their scholastic test scores on the curriculum unit assessed as being predominantly concrete operational.

4. There is no significant difference between scholastic test scores on previous curriculum units of Comparison Group students and their scholastic test scores on the curriculum unit assessed as being predominantly formal operational.

5. There is no significant difference between cognitive level scores of males and females.

Procedures

This study involved the total ninth-grade population of a selected junior high school. The data for the study included scores of 133 heterogeneously grouped, ninth-grade students, on the Cognitive Analysis Project Incidents, the Embedded Figures Test, scores from tests on selected science units and scores from previous science tests. Additional data collected included age and sex.

Permission for conducting the study was obtained from the Superintendent of Schools for the school district in which the study took place. Permission was also obtained from Dr. John Renner, Director of the Cognitive Analysis Project, for use of the CAP Incidents. Following receipt of permission to implement the study, the researcher met with the school principal, the guidance counsellor, and the two teachers to provide only the essential information needed to assist in this study.

In January, 1979, the researcher administered three CAP Incidents and the Group Embedded Figure Test to all students in the ninth grade.

The CAP Incidents and the Group Embedded Figures Tests were scored, and each score was placed into a regression equation to derive a score which would indicate the level of cognitive development for each student as correlated with an entire Piagetian task interview. These scores were then categorized by cognitive level, age in months, and sex.

The general conceptual or operational level of the textual material taught was categorized, as being concrete or formal operational, by a panel of experts in the field of science education, from a Piagetian perspective. The panel approach was selected because no validated instrument could be found which would assess a curriculum unit as being written at a concrete or formal operational level.

A panel of three was selected on the basis of their recognition as experts in the field of Piagetian studies. Each of the panel members was asked to analyze specific chapters in two selected science texts and to categorize each chapter as either consisting of more concrete operational concepts or more formal operational concepts.

The panel members are identified in Appendix B. It should be noted, however, that although no specific criteria were applied to the curriculum units, each member of the panel tended to refer to a list[14] indicating the relationships between concrete and formal concepts which were found in five physics texts and reported in an article by Renner and Grant.[15]

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[14] John W. Renner and Rosalie M. Grant, "Identification of Concrete Operational Concepts and Related Formal Operational Concepts," unpublished paper, University of Oklahoma, 1977.

The specific curriculum unit selected for analysis was Temperature and Heat, a physical science topic. The texts selected included Physical Science: A Modern Approach,[16] a student text used in ninth-grade Science classes in New Brunswick, Canada, and Exploring Matter and Energy,[17] also a student text, being considered as a replacement for the former text by the Curriculum Development Advisory Committee on Science Education. The chapter dealing with Temperature and Heat, in each book, presented similar concepts.

There was general agreement among the panel that the curriculum unit in Physical Science: A Modern Approach was more formal operational in nature, whereas the curriculum unit in Exploring Matter and Energy contained more concrete operational concepts. The latter text was used with three experimental groups and the former text with two comparison groups.

Following the review of the results from the GEFT and CAP instruments, three classroom groups were designated experimental and two were designated as comparison. Each group consisted of a representation of students who were identified as concrete, transitional, and formal operational. The teacher with three classes had two experimental groups and one comparison group, whereas the teacher with two classes had one group of each.

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[15] John W. Renner and Rosalie M. Grant, "Can Students Grasp Physics Concepts?" The Science Teacher, Vol. 45, No. 7 (October, 1978), 24-28.

[16] Charles L. Bickell, et al., Physical Science: A Modern Approach (Toronto: D. Van Nostrad Company [Canada] Ltd., 1968).

[17] Milo K. Blecha, et al., Exploring Matter and Energy (Toronto: Doubleday Canada Limited, 1978). Chapter 7 was the curriculum unit analyzed.

The teachers, who were not aware of the specific purpose of the study, taught from the respective curriculum units during the months of April and May, 1979. At the end of the instructional period both teachers administered objective tests. Each teacher scored the tests and recorded the students' scores.

The scores on three previous science units were also obtained from the teachers' records reflecting scholastic achievement on two physical science units and one biology unit.

Statistical tests were applied to test the five hypotheses. A _t_-test was applied to determine the significance of difference between scholastic test scores of concrete operational students on concrete and formal operational curriculum units, respectively. A _t_-test determined the significance of difference between scholastic scores of transitional and formal operational students on concrete and formal operational curriculum units, respectively. Paired _t_-tests were applied to determine the significance of difference between the scholastic test scores from previous curriculum units for the Experimental and Comparison Groups and their scholastic test scores on assigned curriculum units.

A cross-tabulation of cognitive levels by sex was applied to determine the relationship between the scores of males and females.

Significance of the Problem

It is possible that non-formal operational students may be learning less and receiving lower grades because of their Piagetian cognitive developmental levels.

A review of research is suggestive but not conclusive that there is a significant relationship between scholastic test scores and the ability of students to perform formal operational tasks. The majority of studies tend to focus on senior high and college level students. A computer search[18] supports the notion that few studies have focused on junior high and/or middle school students, in regard to relationships between scholastic test scores, textual material, and cognitive development.

The primary concern of this study is that many junior high school students, while not yet at the formal junior high school students, while not yet at the formal operational stage of intellectual development, nevertheless are being expected to cope with textual material written on an abstract level.

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[18] The computer search included ERIC and Psychological Abstracts.

Piaget's conception of educational practice has been described as

> guiding a developing organism through the stages of intellectual growth, providing him with appropriate organization of subject matter (curriculum), introducing information at appropriate time levels . . . in an appropriate manner (teaching strategy).[19]

Taking the learner into account in teaching and curriculum development appears to be the simplest of platitudes, but yet remains the most crucial consideration in providing meaningful and effective education.

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[19] Irving E. Sigel, "The Piagetian System and the World of Education," Studies in Cognitive Development, eds. David Elkind and John H. Flavell (New York: Oxford University Press, 1969), p. 466.

CHAPTER 2

A REVIEW OF PIAGET'S STAGES OF INTELLECTUAL DEVELOPMENT

> The child can receive valuable information via language or via education directed by an adult only if he is in a state where he can understand this information. That is, to receive the information he must have a structure which enables him to assimilate this information.[1]

The publication of Jean Jacques Rousseau's _Emile_ in 1762 introduced a revolutionary idea into educational philosophy, namely, that sound pedagogy should be based upon a knowledge of child development. This idea has now become a fundamental principle of educational practice, and pedagogical styles often follow new discoveries or theories in the field of child development.

Looming large in the world of educational practice today are the ideas and experimental discoveries of Jean Piaget, Director of the International Center of Genetic Epistemology in Geneva, Switzerland. Piaget has been studying the qualitative changes in the thought processes of children for more than fifty years and has only recently given systematic attention to the period of adolescence. Prior to 1960, this qualitative approach was not readily was not readily accepted by North American developmental psychologists who were primarily behavioristic in their emphasis.

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[1] Jean Piaget, "Development and Learning," _Piaget Rediscovered_, eds. R. E. Ripple and V. N. Rockcastle (Ithica, New York: Cornell University Press, 1964), p. 13.

In the 1960's, the psychological pendulum began to swing from a strict behaviorist approach toward a more cognitive and personalistic view of the child. By the mid-1960's American psychologists had conducted scores of Piaget-based studies and many papers on child development presented at psychological conventions were either based on or at least referred to Piaget's work.

While Piaget himself has hardly dealt with the problems of education or with other practical applications of his theory of intellectual development, psychologists and educators have recently begun to appreciate the importance of his thoughts and work.

In his theory, intellectual development evolves through four stages in the growth of the child. These are the Sensorimotor stage (age 0-2 years), the Preoperational stage (age 2-7 years), the Concrete Operational stage (age 7-11 years) and the Formal Operational stage (age 11-16 years). The stages are of invariant sequence, but may vary as to duration and chronological age.[2]

The primary purpose of this chapter is to present a concise description of the thoughts and work of Piaget through an understanding taken primarily from the writings of educational psychologists who have interpreted his work.

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[2] John H. Flavell, The Developmental Psychology of Jean Piaget (New York: Van Nostrand, 1963), p. 264.

Before examining the theory it might be advantageous to consider Piaget's conception of intelligence.[3] His non-restrictive definition states that "intelligence involves biological adaptation, equilibrium between the individual and his environment, and a set of mental operations which permit this balance."[4]

Any specific learning rests on the basis of the general development of intelligence. "Learning can only take place on condition that the child has general mechanisms to which he can assimilate the information contained in learning."[5] In this regard, intelligence is the most necessary instrument of learning.

Piaget's theory of intellectual development has two dimensions that are closely related: the stage-dependent dimension and the stage-independent dimension.[6] The stage-independent aspects of the theory concern the nature of the human subject and his development in general.[7] The stage-dependent theory divides intellectual development into four major periods: sensorimotor, preoperational, concrete operational and formal thought.[8] This study will deal primarily with the latter two.

---

[3] Piaget's approach to the psychology of intelligence has been influenced by his two major interests--biology and epistemology. The biological concern results in definitions of intelligence in general terms of growth, stages, adaptation, equilibrium, and similar factors. The epistemological focus has resulted in the empirical investigation of the child's understanding of space, time, causality, and similar notions.

[4] Herbert Ginsburg and Sylvia Opper, Piaget's Theory of Intellectual Development (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1969), p. 24.

[5] Hans G. Furth and Harry Wachs, Thinking Goes to School (New York: Oxford University Press, 1974), pp. 12-13.

The Sensorimotor Stage

The sensorimotor stage of development (birth to 2 years) is subdivided into six developmental phases.[9]

In the first phase (birth to 1 month),[10] the newborn depends heavily on his reflexes for interaction with the world around him.

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[6] John H. Flavell, The Developmental Psychology of Jean Piaget (New York: Van Nostrand, 1963), p. 261.

[7] In addition, Piaget has developed a system of interrelated developmental concepts, such as assimilation, accommodation, adaptation, and equilibration, which cut across his stage theory.

[8] Ginsburg and Opper, op. cit., p. 26.

[9] In his earlier work, Piaget focused on cognitive development in infancy and early childhood. Two of his early books, The Origins of Intelligence in Children (1952) and The Construction of Reality in the Child (1954), are primarily devoted to the period of development from birth to age 2. (Dates given in parentheses are the first publication dates of the English translations.)

[10] It should be emphasized that the age limits of each stage or phase of intellectual development are only approximate and that Piaget stresses the flexibility of the age norms. However, regardless of the particular ages, the stages are in a regular order of succession.

In the second phase (1 to 4 months), the primary circular reactions or reflexes are replaced by voluntary movements. It is during this phase that the infant learns in a primitive way to anticipate future events and to show an interest in events that are moderately novel.

> One observes that the subject looks neither at what is too familiar, because he is in a way surfeited with it, nor at what is too new because this does not correspond to anything in his schemes. . . .[11]

Another accomplishment of the second phase concerns "passive expectation."[12] The infant follows a moving object with his eyes until it leaves his visual field. He continues to stare at the spot where the object disappeared. This passive expectation is the first step toward the later active search for the missing object and hence toward acquisition of the object concept.[13]

In phase three (4 to 8 months), the infant's behaviour and interest extend beyond his own body, and he makes more extensive, but still immature, contact with the external environment. The infant develops secondary circular reactions. By chance, he discovers an interesting environmental event and attempts to rediscover the actions which produced it. Piaget maintains that the secondary circular reaction does not yet constitute intelligent behavior.

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[11] Jean Piaget, The Origins of Intelligence in Children, trans. M. Cook (New York: International University Press, 1952), p. 68.

[12] Ginsburg and Opper, op. cit., p. 43.

[13] An "object," according to Piaget, is something which the individual conceives of as having a reality of its own, and as extending beyond his immediate perception.

In the fourth phase (8 to 12 months), the infant's behavior is increasingly systematic and well organized. As the concept of "object permanence" emerges, a child will search for a toy hidden under a blanket. By interacting with his environment, he learns about relations of objects. This behavior is purposive and therefore intelligence is being employed.

Phase five (12 to 18 months) is the climax of the sensorimotor period.[14] The infant shows an active interest in producing new behavior and novel events. This interest in novelty for its own sake is called a tertiary circular reaction.[15] In regard to the sensorimotor development of the concept of object permanence, the infant can now search for and find the object even through a series of displacements. However, he is not as yet capable of inference.

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[14] Ginsburg and Opper, op. cit., p. 67.

[15] Ibid., p. 59.

The final phase (18 to 24 months) is that of internalization of sensorimotor schemata. There is a transition to symbolic thought which enables the child to represent mentally an object or action which is not perceptually present.

Sensorimotor intelligence"acts like a slow-motion film, in which all the pictures are seen in succession but without fusion, and so without the continuous vision necessary for understanding the whole."[16]

In summary, the sensorimotor period is characterized by the development of the sensorimotor reflexes and actions, eye-hand coordination, means-ends relations, and the awareness of the permanent object. The theme of this stage is that the infant is active; that is, he seeks contact with the environment.[17]

The Preoperational Stage

The second stage of development (2 years to 7 years) is the preoperational or representational stage which extends from the beginnings of organized symbolic behavior--language in particular--until about 6 years.[18]

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[16] Jean Piaget, The Psychology of Intelligence (London, England: Routledge and Kegan Paul, 1950), pp. 120-121.

[17] Ginsburg and Opper, op. cit., p. 70.

[18] Inhelder and Piaget, op. cit., p. xii.

From research in Geneva and elsewhere, certain characteristics of mental processes at the preoperational stage have been identified. The child is perceptually oriented; he makes judgements in terms of how things look to him. He centers on one visible variable and therefore lacks the ability to coordinate variables. The child, at this developmental stage, also has difficulty in realizing that an object can possess more than one property, and that multiple classifications are possible.

The preoperational stage may be divided into two phases: that of preconceptual or symbolic thought, from 2 to 4 years, and intuitive thought from 4 to around 7 years.[19]

The first phase, that of preconceptual thought, is characterized by the development of the symbolic function evidenced in language and symbolic play. Language plays a limited, but not negligible role in the formation of the child's thought. The child often thinks non-verbally by forming mental symbols which are based on imitations of things and not on their names.[20] Language skills are developed during this phase in order to communicate thought.

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[19] Richard M. Gorman, Discovering Piaget: A Guide for Teachers (Columbus, Ohio: Charles E. Merrill Publishing Company, 1972), p. 14.

[20] Ginsburg and Opper, op. cit., p. 85.

The second phase, that of intuitive thought, is characterized by syncretism (a fusing together in understanding) and transductive reasoning (one fact explains another). The child is still very dependent on his sensory impression. He does not yet comprehend the principle of conservation nor does he think in terms of a hierarchy of classes.

In essence, Piaget suggests the following:

> The preoperational stage, then, is really a period during which the child goes from the stage where he operates only by direct action on the objects (sensory motor) to a stage where he is capable of operating with a coherent and integrated cognitive system (concrete operations).[21]

At approximately age 7 or 8, a major shift in the child's conceptual development takes place. Piaget calls this stage the stage of concrete operations, because, when the child uses logical operations, the content of his thinking is concrete rather than abstract.[22]

An understanding of the difference in cognition at the preoperational and concrete operational stages requires a knowledge of the term "operation"[23] as used in this sense. To Piaget the idea of an operation is central to the entire understanding of the development of knowledge. Knowledge in this sense is not a copy of reality, but rather the result of certain action carried out in regard to reality. To know an object or event, one must not only look at it, but also modify or transform it (at least mentally). By understanding this process or transformation, the individual comes to realize how the object is constructed. This transformation is what is meant by an operation.

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[21] Herbert D. Thier, Teaching Elementary School Science: A Laboratory Approach (Lexington, Mass.: D. C. Heath and Company, 1970), p. 83.

[22] Celia Lavatelli et al. Elementary School Curriculum (New York: Holt, Rinehart and Winston, Inc., 1972), p. 45.

[23] An operation is an internal manipulation or grouping of objects, concepts, propositions, etc.

For example, an operation could be the joining of objects into a class for classification, or the ordering or seriation of a set of objects by some property, or the counting, or measuring of a group of objects. In all of these four situations, the actions carried out modify the view of the object or event and enable the learner to get at the structures involved. The operation is always linked to other operations and therefore is a part of the total structure.[24]

The Concrete Operational Stage

The older concrete operational child (7 to 11 years) is distinguished from the younger preoperational child by his knowledge of operations. Flavell has described the difference by stating that "the older child has at his command a coherent and integrated cognitive system with which he organizes and manipulates the world around him."[25] In the concrete operational stage, the child is able to observe, judge, and evaluate in less egocentric terms and formulate more objective explanations than in the preoperational stage. But he cannot verbally express hypotheses following a long series of related ideas, or if concrete referents are not available.

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[24] Jean Piaget, "Cognitive Development in Children: Development and Learning," A New Look at Elementary School Science, Robert Karplus and Herbert D. Thier, eds. (Chicago: Rand McNally, 1967), Appendix, p. 172.

The thinking of the concrete operational child can be described as, first, being systematic in behavior. Cognitive decisions seem to spring from a coherent and intercoordinated system of actions. Second, the behavior seems to be permeated with expressions of reversibility.[26] It is reversibility which gives the necessary flexibility of approach to solve a problem and that problem solving ability is characteristic of the concrete operational level.

At the same age that concrete operations become possible, the child's language, which has been predominantly egocentric until the age of 7, becomes primarily sociocentric.

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[25] Flavell, op. cit., p. 165.

[26] Reversibility is the transformation by which a person is able to return to the starting point of a problem or situation after an operation has changed it.

> The child really exchanges his thoughts with others, either by telling his hearer something that will interest him and influence his actions, or by an actual interchange of ideas by argument or even by collaboration in pursuit of a common aim.[27]

The Formal Operational Stage

The final stage of intellectual development is that of formal operations, which begins at about age 12, and is consolidated during adolescence.[28]

Only in his more recent research has Piaget studied the period of adolescence. This trend is reflected in The Growth of Logical Thinking from Childhood to Adolescence.[29]

Given a particular problem, a child at the level of concrete operations is likely to test out a possible solution, reject it if it does not fit, try another, and so on. A student at the level of formal operations, however,

> begins his consideration of the problem at hand by trying to envisage all the possible relations which

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[27] Jean Piaget, The Language and Thought of the Child, trans. M. Gabain (London: Routledge & Kegan Paul Ltd., 1926), p. 33.

[28] Ginsburg and Opper, op. cit., p. 181.

[29] Inhelder and Piaget, op. cit. Reference will be to Piaget and his theory even though Bärbel Inhelder is the senior author of this volume which offers the major source material for the remainder of this chapter.

> could hold true in the data and then attempts, through a combination of experimentation and logical analysis, to find out which of these possible relations in fact do hold true. Reality is thus conceived of as a special subset within the totality of things which the data would admit as hypotheses.[30]

The most important features of this stage are the development of the ability to use hypothetical reasoning based on a logic of all possible combinations and to perform controlled experimentation.

In The Growth of Logical Thinking from Childhood to Adolescence,[31] the stage of formal operations has been subdivided into two distinguishable phases: III-A (11 or 12 to 14 or 15 years), and III-B (14 or 15 years onward).[32]

The reasoning from phase III-A to phase III-B becomes increasingly more abstract and shows a higher degree of mastery of the formal operations. Phase III-A is a preparatory period in which the subject may handle certain formal operations and make correct discoveries, but he is not able to provide systematic proof. In the second phase (III-B) the subject is capable of providing systematic proof by using methods of control. He is also able to formulate more elegant generalizations and to develop more inclusive laws.[33]

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[30] Flavell, op. cit., p. 204.

[31] Inhelder and Piaget, op. cit.

[32] Ibid., p. 1.
Inhelder and Piaget identify three stages: Stage I (up to about 7-8 years); Stage II (from 7-8 to 11-12 years); and Stage III (from 11-12 years onward).

The adolescent not only thinks beyond the present, but analytically reflects about his own thinking. He can leave the real objective world behind and enter the world of ideas. He begins by thinking of all logical possibilities and then considers them in a systematic fashion; reality to him is secondary to possibility.

> The most distinctive property of formal thought is this reversal of direction between reality and possibility; instead of deriving a rudimentary type of theory from the empirical data as is done in concrete inferences, formal thought begins with a theoretical synthesis implying that certain relations are necessary and thus proceeds in the opposite direction. . . . This type of thinking proceeds from what is possible to what is empirically real.[34]

Piaget's and Inhelder's theory of adolescent thought may be stated in terms of two logical models--the sixteen binary operations[35] and the INRC group.[36] These two models together describe the period of formal operations.

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[33] Rolf E. Muuss, Theories of Adolescence (New York: Random House, 1969), p. 160.

[34] Inhelder and Piaget, op. cit., p. 251.

[35] The model of the sixteen binary operations is actually a special case of a larger and more comprehensive system called the combinatorial system. This special case applies to situations involving two values (e.g., p and $\bar{p}$) of each of two factors (e.g., p and q). With a greater number of factors, more complex models are necessary and can be generated from the combinatorial system. The combinatorial system is a structured whole of all possible combinations of objects, ideas or propositions.

[36] The INRC group: The subject is able to relate the following operations and transformations into an integrated system: Identity (I) is the thing itself or

Sixteen Binary Operations

The system of sixteen binary operations[37] of propositional logic includes complete affirmation (p*q) and its negation (0). The formation of the operation p*q is the assertion of the possible occurrence of any one of the four base associations ($p.q \vee p.\bar{q}\ \bar{p}.q \vee \bar{p}.\bar{q}$). The third and fourth operations are conjunction (p.q) and its inverse, incompatability (p/q). Conjunction may have either one of two meanings, when the association p.q. is linked to others and when association p.q is the only true combination. Two factors must come together before a given result can be obtained. Incompatability means that the characteristics denoted by p and q are not conjunctive: where one is present the other or both are absent.

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the basic operation. Inversion (N) is the transformation which negates the basic operation. Reciprocity (R) is the transformation which compensates or makes up for the effect of the basic operation. Correlation (C) is the operation that has the same effect as the basic operation (or negatively, the inverse of that reciprocal).

[37] In the case of the propositional combinatorial system, the elements are the associations $p.q$, $p.\bar{q}$, $\bar{p}.q$, and $\bar{p}.q$, which are not mutually equivalent and are even qualitatively quite distinct. The associations are stated and relate to objects or qualified events, which implies a greater degree of abstraction.

Disjunction (pvq) and conjunction negation $(\bar{p}.\bar{q})$ are the fifth and sixth operations respectively. Disjunction signifies that p is true or q is true or both are true. An effect may be due to two causes acting separately or conjointly. The negation is expressed by the simultaneous absence of both causes.

The next two operations are implication $(p > q)$ and nonimplication $(p.\bar{q})$. Implication is employed each time a cause expressed by p produces an effect, expressed by q, but is not the only cause which can produce the same effect. The negation of implication is employed to prove nonintervention of a possible factor.

The ninth and tenth operations are reciprocal implication $(q > p)$ and its negation $(p.q)$. The operation $q > p$ has no distinct consequences except as compared to an operation $p > q$ already determined or in the course of being determined. The negation may be expressed similarly to that of nonimplication.

Equivalence $(p = q)$ refers to the assertion that two propositions are always both true or both false. It could also be expressed as the product of two implications $p > q$ and $q > p$. Reciprocal exclusion $(pvvq)$ is the integration of two nonimplications $p.\bar{q}$ v $\bar{p}.q$ and is therefore the negation of equivalence.

The affirmation $(p[q])$ and negation $(\bar{p}[q])$ of p are the next operations to be described. The former affirms that p is true when q is either true or false. The latter denies that p is true when q is either true or false.

The final two operations of the system are the affirmation (q[p]) and negation ($\bar{q}$[p]) of q.

The following experiment will illustrate several aspects of a combinatorial system of propositions.[38]

Problem #3. The subject is given two dice and told to throw them onto a table several times and keep track of the results. The inner portion of the table is red metal, while the outer portion is white wood. Opposite the "1" on the die a magnet is imbedded.

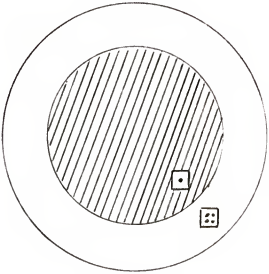

Figure 1

A Table Top Designed to Illustrate, with the Aid of Dice, Several Aspects of a Combinatorial System of Propositions

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[38] Gorman, op. cit., p. 35. This problem has been

Ed, age 14: "The 'one' shows more than any other." Why should that be? "Maybe there's a weight in one of them."

More tries. "It's not a weight because 'one' doesn't always show." How can you prove that?

1 Well, there's either a weight in one die that always makes it come up 'one,' or if it doesn't always come up 'one' there's no weight.

2 Let's see, it has to be either the dice or the table that causes it, or maybe both." More tries.

3 "When the 'one' comes up it's always on the red, so it's both the dice and the middle part [of the table] that have something to do with it."

4 "It's probably a magnet because if there's a magnet on one of them it will land the same way on the metal center part.

5 What is the real cause? "It's both. The magnet causes the die to land with 'one' up and the die shows 'one' because it lands on the metal. It's the same thing."[39]

The transcript indicates that the subject employed a systematic approach by setting up hypotheses in terms of possible combinations of ideas and causes.

In the first section, the subject excluded weight as a possibility and used an "either-or" approach (mutual exclusion).

In the second section, the subject combined the possibilities in what is termed a "distinctive" way:

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adapted from The Growth of Logical Thinking from Childhood to Adolescence by Bärbel Inhelder and Jean Piaget, Basic Books, Inc., Publishers, New York, 1958.

[39] Ibid., pp. 35-36.

either the dice or the table or both.

In the third section, the subject joined the dice and the middle part of the table together (conjunction) as a "joint possibility."

In the fourth section, the subject states that a magnet implies or is connected in a causal way with landing the same way on the metal part. An "if-then" type of thinking is inferred.

In the final section, the subject connects two statements in a relation of equivalence.

The above sample provides an initial idea of the propositional operations which, when taken together, form a complete combinatorial system, or "structured whole" of possibilities.[40]

The INRC Group

Following the analysis of functions or of the binary operations, Piaget and Inhelder go on to describe how the adolescent manipulates the conclusions which he has derived from an experiment. For this purpose, they introduce another logical model, the INRC group. The INRC group is an attempt to specify the rules which the adolescent uses in manipulating or transforming functions. There are four such rules: Identity (I), Negation (N),

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[40] Ibid., p. 37.

Reciprocity (R), and Correlativity (C).[41] Each of the four letters stands for one of the logical transformations which can be performed on a propositional operation, changing it into a different operation.

The identity or null transformation results in no basic change; the original proposition retains its identity. In an "N" transformation, everything in a given proposition is changed into the opposite of the original proposition. "All assertions become negations, and vice versa, and all conjunctions become disjunctions, and vice versa."[42] The reciprocal (R) of a proposition transforms the proposition without changing the conjunction or disjunction that joins the parts of the proposition. Piaget and Inhelder refer to the correlative (C) as the reciprocation of the inverse; in other words, this transformation changes the conjunction or disjunction which joins the parts of the proposition, but does not transform the remainder of the proposition.

> The 16 binary operations and the INRC group are not intended to imply that the adolescent understands logic in any explicit way. Most adolescents do not know propositional logic or group operations. Piaget does not use logic to describe the adolescent's explicit knowledge, but to depict the structure of his thought.[43]

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[41] Ginsburg and Opper, op. cit., p. 196.

[42] Flavell, op. cit., p. 216.

[43] Ginsburg and Opper, op. cit., p. 200.

No model is ever definitive. In fact, Piaget and Inhelder are presently engaged in an elaboration of these two logical models.[44]

There are several major themes which run through Piaget's and Inhelder's account of adolescent thought. One is that the adolescent's system of mental operations has reached a high degree of equilibrium. In other words, his thoughts are flexible and effective enough to deal efficiently with the complex problems of reasoning. The adolescent is unlikely to be confused by unusual results because he has previously conceived of the many possibilities inherent in a situation. Another major theme is that the adolescent's thought can proceed in one direction, and then use several different methods for retracing its steps in order to return to the point of origin.

In the intellectual sphere, the adolescent has a tendency to become involved in theoretical matters. He exercises, without restraint, his newly discovered capabilities for abstract thought.

There are basic differences between the thought processes of the adolescent and those of the younger child.

> The preoperational child is the child of wonder; his cognition appears to us naive, impression-bound,

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[44] Ibid., p. 201.

> and poorly organized. . . . The child of concrete operations can be caricatured as a sober and bookkeeperish organizer of the real and a distruster of the subtle, the elusive, and the hypothetical. The adolescent has something of both: the 7-11-year-old's zeal for order and pattern coupled with a much more sophisticated version of the younger child's conceptual daring and uninhibitedness. Unlike the concrete-operational child, he can soar; but also unlike the preoperational child, it is a controlled and planned soaring, solidly grounded in a bedrock of careful analysis and painstaking accommodation to detail.[45]

Piaget's and Inhelder's findings suggest that there are basic differences between the adolescent and younger child as far as scientific reasoning is concerned. It seems clear that as the child progresses through the various stages of intellectual development "there is an improvement in systematic experimentation, in the design of crucial tests, in attempts to isolate variables, in the appreciation of the complexity of problems, and in the ability to draw reasonable conclusions from empirical data."[46]

Piaget's and Inhelder's primary interest, in any stage of intellectual development, is in the quality of thought or in the process used in arriving at solutions. The issue is whether and how the thought of the adolescent differs from that of the younger child. Their interest is in how the adolescent attacks scientific problems, how he experiments, and how he reasons about the observed data.

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[45] Flavell, op. cit., p. 211.

[46] Ginsburg and Opper, op. cit., p. 206.

CHAPTER 3

A REVIEW OF RESEARCH

This review of research focuses on investigations into relationships that may exist between scholastic test scores, textual material and Piagetian cognitive development stages.

The following is a review of studies (a) reporting the developmental level of early adolescents and young adults, (b) showing the relationship between cognitive development and science achievement, (c) reporting research findings on brain growth, (d) reporting on the current status of science instruction for early adolescents, and (e) reporting research findings on science curricula for early adolescents. The chapter concludes with a discussion of the research.

Studies Reporting the Developmental Level of Early Adolescents and Young Adults

Higgins-Trenk and Gaite[1] concluded from their study on formal operations with American subjects "that formal adolescents are unlikely to reach the level of formal thinking until their late teens or early twenties if they reach it at all." Kohlberg and Gilligan[2] concluded that all normal children reach the formal operational level of reasoning. Howe[3] stated "that it would be a mistake to assume that even upper-level secondary students, except those who are very able, have access to formal operations for the solution of most problems."

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[1] A. Higgins-Trenk and A. J. H. Gaite, "Elusiveness of Formal Operational Thought," Proceedings 79th Annual

Renner[4] found that among students in grades 10 through 12 only 9 percent were fully formal operational. Lovell[5] reported that a number of adolescents may reach the formal operational level in limited areas for short periods of time or fail to reach this level at all. These findings are supported by Elkind,[6] Kolhberg and Mayer,[7]

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[2] L. Kohlberg and C. Gilligan, "The Adolescent as Philosopher: The Discovery of the Self in a Postconventional World," Daedalus, Vol. 100, No. 4, 1971, 1051-1085.

[3] A. Howe, "Formal Operational Thought and the High School Science Curriculum," Paper presented at the National Association for Research in Science Teaching Annual Meeting, Chicago, April, 1974.

[4] J. W. Renner, Evaluating Intellectual Development Using Written Responses to Selected Science Problems, Report to the National Science Foundation on Grant Number EPP 75-19596, "Analysis of Cognitive Process," 1977.

[5] K. Lovell, "A Follow-Up Study of Inhelder and Piaget's 'The Growth of Logical Thinking,'" British Journal of Educational Psychology, Vol. 52, 1961, 143-154.

[6] D. Elkind, Child Development and Education (New York: Oxford University Press, 1976).

[7] L. Kohlberg and R. Mayer, "Development of the Aim of Education," Harvard Educational Review, Vol. 42, 1972, 449-496.

Renner et al.,[8] and Schwebel.[9] Kavanaugh,[10] Chiappetta,[11] and Abramowitz[12] report research findings that a large proportion of early adolescents are still at the concrete operational level.

Piaget[13] and Renner and Stafford[14] have shown that children begin to leave the preoperational stage of intellectual development near the end of the first grade--at approximately 7 years of age. Therefore, the majority of time that children are in school their reasoning patterns are concrete, or formal, or somewhere between those two stages (such persons may be referred to as "transitional" or "post-concrete").

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[8] J. Renner, D. Stafford, A. Lawson, J. McKinnon, F. Friot, and D. Kellog, Research, Teaching and Learning with the Piaget Model (Norman, Oklahoma: University of Oklahoma Press, 1976).

[9] M. Schwebel, "Formal Operations in First Year College Students," Journal of Psychology, Vol. 91, 1975, 133-141.

[10] D. E. Kavanaugh, "An Investigation of Portions of a Model Hierarchy for the Acquisition of the Concept of Speed" (PhD dissertation, University of Iowa, 1972).

[11] E. L. Chiappetta, "A Perspective on Formal Thought Development," Paper presented at the annual meeting of the National Association for Research in Science Teaching, Los Angeles, California, March, 1975.

[12] S. Abramowitz, "Investigation of Adolescent Understanding of Proportionality" (PhD dissertation, Stanford University, 1974).

[13] Jean Piaget, The Psychology of Intelligence (London: Routledge and Kegan Paul Ltd., 1950).

[14] John W. Renner and Donald G. Stafford, Teaching Science in the Secondary School (New York: Harper and Row, 1972).

Renner and Stafford[15] assessed the developmental level of 298 junior high school students (grades 7, 8 and 9) living in various parts of Oklahoma. They used six Piagetian tasks to assess development. The results show that 77 percent were concrete operational, 13 percent were postconcrete operational, and 6 percent were formal operational.

Lawson and Blake[16] assessed the abstract thinking ability of 68 high school biology students in a rural high school located in North Central Indiana. The students ranged in age from 14 years 7 months to 17 years 10 months. Each subject was presented with three Piagetian tasks. The researchers reported that 47 percent were concrete operational and 53 percent were formal operational.

Nordland et al.[17] determined the developmental level of 506 randomly selected science students from a sneior high school with a predominantly black student population. The subjects ranged in age from 13 years 6 months to 20 years 0 months. They were given 10 Piagetian tasks.

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[15] Ibid.

[16] A. E. Lawson and A. J. D. Blake, "Concrete and Formal Thinking Abilities in High School Biology Students as Measured by the Separate Instruments," unpublished paper, Lawrence Hall of Science, University of California at Berkeley, November, 1974.

[17] F. Nordland, A. E. Lawson, and J. B. Kahle, "A Study of Levels of Concrete and Formal Reasoning Ability in Disadvantaged Junior and Senior High School Science Students," Science Education, Vol. 58, No. 4, 1974, 569-575.

The results show that 85.8 percent of the students were at the concrete operational stage, while 13.2 percent were at the formal operational stage.

The following studies give evidence of some specific formal abilities which may emerge during the early adolescent period. All of these studies were based on Piaget's theory. Lovell[18] and Jackson[19] have demonstrated the emergence of formal operations around the age of 11 to 12 on a wide variety of tasks. They also found support for continued improvement through late adolescence. Lunyer and Pumfrey[20] and Pumfrey[21] found that proportionality, the skill of equating two ratios, did not often appear before the age of 14.

Karplus, Karplus, Formisano and Paulsen[22] found that less than one-fourth of 13 and 15 year olds used formal operations on "proportional reasoning" and "controlling variables" problems. Linn and Levine[23] found that formal operations were not used by all early adolescents in solving logical problems of the "controlling variables" type, but familiarity with the variables used influenced success rates.

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[18] K. Lovell, The Growth of Basic Mathematical and Scientific Concepts in Children (London: University of London Press, 1961).

[19] S. Jackson, "The Growth of Logical Thinking in Normal and Subnormal Children," British Journal of Educational Psychology, Vol. 35, 1965, 255-258.

[20] A. E. Lunyer and P. D. Pumfrey, "Understanding Proportionality," Mathematics Teacher, Vol. 34, 1966, 7-120.

[21] P. Pumfrey, "The Growth of the Scheme of Proportionality," British Journal of Educational Psychology, Vol. 33, 1968, 202-204.

[22] R. Karplus, E. Karplus, M. Formisano, and A. Paulsen, Proportional Reasoning and Control of Variables in Seven Countries, Advancing Education Through Science Oriented Programs: Report 10-25 (Berkeley, California: Lawrence Hall of Science, 1975).

These results indicate that some formal operational abilities are emerging during the early adolescent period, but abilities such as "controlling variables" (the strategy of holding other things constant in explaining the effect of one variable on an outcome) may be atypical among early adolescents. The results of Karplus and others[24] suggest that performance on some of the experimental tasks used in this research may be influenced by instruction, but further research is required to establish the degree of teachability of these skills at the early adolescent level.

Weeks[25] conducted a study to determine the development of formal operation abilities among junior high school students and to relate this development to differences in grade, sex, socio-economic status, scholastic aptitude, and school achievement. The sample of 190 seventh graders, 195 eight graders, and 175 ninth graders was divided approxmately equally by sex.

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[23] M. C. Linn and D. I. Levine, Adolescent Reasoning: The Development of the Ability to Control Variables, Advancing Education Through Science Oriented Programs: Report PSC-9 (Berkeley, California: Lawrence Hall of Science, 1976).

[24] Karplus et al., op. cit.

[25] Ruth T. Weeks, "The Relationship of Grade, Sex, Socio-Economic Status, Scholastic Aptitude, and School Achievement to Formal Operations Attainment in a Group of Junior High School Students" (PhD dissertation, Kent State University, 1973).

Three tests were used to measure the development of formal operations: Piaget's test of conservation of volume, Peel's story test to measure logical reasoning, and Neimark's test of the understanding of the correlative "or" to measure ability to use combinatorial analysis. An adaptation of Warner's scales was used to assess socioeconomic status and part of the Differential Aptitude Test was used to assess scholastic aptitude. The major findings were twofold:

1. There was a significant difference on the three measures of formal operation between the scores of seventh and of ninth grade students ($\underline{p} < .01$). However, the differences between the adjacent grades were not consistently significant on the three measures. At the ninth grade level, 69.1 percent of the students were at the formal operations level on the conservation of volume test; 56.0 percent on the Peel test; and only 38.3 percent on the Neimark Test. These differences in test results and the low correlations between the tests suggest that formal operations is not a unitary function.

2. There was a significant sex difference at the eighth and ninth grade levels ($\underline{p} < .01$) on conservation of volume with more boys than girls being successful, while

there was a significant sex difference at the seventh grade level on the Peel test, and at the eighth grade level on the Neimark Test ($p < .01$) with more girls than boys being successful in both instances. Again, the different tests yielded different results. The major sex difference finding is that there were more consistent differences between the grades for the boys and little change for the girls.

Research on Cognitive Development and Science Achievement

An analysis of research relating cognitive development to science achievement indicates that the majority of adolescents and young adults function at the concrete operational level when it comes to understanding much of the science content taught at the secondary and at the college level.

Farrell[26] has stated that formal operational individuals have the capacity to use formal operations but are not always compelled to do so. Individuals may frequently revert to earlier stages of cognitive functioning.

Sheehan[27] studied the effectiveness of concrete and formal instructional procedures with concrete and formal operational students. A sample of 104 science students was randomly chosen from a population of all students between the ages of 12 years 6 months and 13 years 5 months who attended a school district in upstate New York. The students were classified as either concrete or formal operational by using tests developed by Longeot,[28] which were based on Piaget's theory of cognitive development. Some of the characteristics of the concrete instructional procedures were that real concrete materials and/or events were used; when two or more variables were involved only one was dealt with at a time; non-hypothetical statements were employed; and deductive reasoning was eliminated. With the formal instruction, propositions and hypothetical situations were used along with deductive statements; in addition the consideration of all possible variables was required. The effects of instructions were measured by students' understanding of equilibrium in the balance bar, of angles, of evidence and reflection, and of the oscillation of a pendulum.

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[26] M. A. Farrell, "The Formal Stage: A Review of the Research," Journal of Research and Development in Education, Vol. 3, No. 1, 1969, 111-118.

[27] D. Sheehan, "The Effectiveness of Concrete and Formal Instructional Procedures with Concrete and Formal Operational Students" (PhD dissertation, Michigan State University, 1970).

At the start of the study, Sheehan hypothesized that subjects classified as formal operational would score higher on criterion measures after formal instructional procedures than after concrete instructional procedures. However, the reverse was found to be true. Formal operational subjects achieved significantly higher scores as a result of concrete instruction than from formal instruction. Sheehan recognized the regression effect in his discussion of the improved performance of formal operational subjects from concrete instruction, but not from formal instruction.

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[28] F. Longeot, "Un Essay D'Application de la Psychologie Genetique à la Psychologie Differentielle," BINOP No. 3 (Bulletin de L'Institut National D'Etude Du Travail et Orientation Professionelle), 1962, Analyse Statistique de Trois Tests, Genetiques Collectifs. BINOP No. 4 (Bulletin de L'Institut National D'Etude Du Travail et D'Orientation Professionelle), 1965, 219-273.

This finding is somewhat unexpected. It might be conjectured that, once a person has reached the highest level in concrete thought, any additional increase in intellectual development would make no contribution to the understanding of concrete concepts. The indication is, however, that formal thought does contribute to the understanding of concrete concepts.

Renner[29] states that formal thought contributes to the understanding of concrete concepts. He suggests two tentative explanations for this finding:

> 1. Formal operations may help in the understanding of concrete concepts by the elucidation of a more comprehensive system of both concrete and formal content. This larger frame-of-content reference allows the learner to see relationships involving concrete objects, situations, or events previously unrecognized. This expanded frame of reference thereby brings deeper meaning to concrete as well as formal content.
> 2. The teaching procedures used in the classrooms are largely expository; consequently, students seldom are confronted with first hand concrete experiences

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[29] John W. Renner, Donald G. Stafford, Anton E. Lawson, Joe W. McKinnon, F. Elizabeth Friot, and Donald H. Kellogg, Research, Teaching, and Learning with the Piaget Model (Norman, Oklahoma: University of Oklahoma Press, 1976), pp. 170-171.

> with any aspects of the discipline. These procedures, in effect, render potentially concrete material abstract or formal, and the learner does not, therefore, have the opportunity to develop understanding of it until he enters the formal stage.

Sayre and Ball[30] explored the relationships between scholastic grades in science in junior and senior high school students and the ability of students to perform operational tasks at the formal stage of intellectual development. For this study, 419 students enrolled in eight Weld County (Colorado) Reorganized School Districts during Fall semester, 1971, served as the sample.

A Piagetian Task Instrument (PTI) was utilized. Students successfully completing four or more of the five criterion tasks of the PTI were classified as formal operational. Students successfully completing three or less of the five criterion tasks were classified as nonformal operational.

The findings of this study indicate that, at certain grade levels and/or subject areas, public school science students who demonstrate formal operational logic tend to receive higher grades than nonformal operational students.

It would appear from the results of this investigation that secondary science institutions should be structured around the cognitive developmental level of the students involved.

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[30] Steve Sayre and Daniel Ball, "Piagetian Cognitive Development and Achievement in Science," Journal of

The researchers hypothesize that teacher expectations from instruction are related to the cognitive levels of the students, a status over which they have little control. Lower grades received by nonformal operational students may be due, in part, to teacher assumptions about their ability.

The researchers suggest that individuals preparing to teach junior or senior high school science should develop an understanding of Piagetian developmental theory to aid them in providing more appropriate instruction for students.

Research on Brain Growth

Recent findings by Epstein[31] indicate that in about 85 percent of children tested the brain discontinues growth in weight between ages 12 to 14. Renner[32] suggests that this slowdown parallels "pubertal metamorphosis" in a large number of youngsters and may provide an explanation for the plateauing of achievement scores on standardized tests often during grades 7 through 9.

Research in Science Teaching, Vol. 12, No. 2, April, 1975, 1965-1974.

[31] Herman T. Epstein, "A Neuroscience Framework for Restructuring Middle School Curricula," Transescence: The Journal of Emerging Adolescent Education, Vol. 5, 1977, 6-11.

[32] Renner et al., op. cit.

Epstein and Toepfer[33] contend that the brain grows during the maturing process from 350 grams to 1400 grams. During specific periods of growth, at 3 to 10 month intervals, spurts of brain growth are reported to occur. Such spurts occur between the ages of 2 to 4, 6 to 8, 10 to 12, and 14 to 16. Data have suggested that there is an apparent peak in learning capacity at about age 11 and a low point at age 13. These spurts of growth coincide with Piaget's classical stages of development and may provide the biological basis for Piaget's theory.

Implications for education could be broad. During periods of slow growth students may have difficulty developing new concepts; horizontal learning might be more appropriate. During grades 7 and 8, the 12 to 14 year old plateau period, a curriculum formulated on the acquisition of new intellectual skills would theoretically prove less effective than one based on improvement of concrete skills already acquired. Epstein and Toepfer[34] hypothesize that students in grades 7 and 8 cannot assimilate new complex materials and, therefore, reject input and develop negative neural networks which continue to remain in force during the 14 to 16 year period. Further, they assert that though students should be able to accept novel cognitive skills at

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[33] Herman T. Epstein and Conrad F. Toepfer, Jr., "A Neuroscience Basis for Reorganizing Middle Grades Education," Educational Leadership, Vol. 36, 1978, 656-660.

[34] Ibid.

Epstein[35] emphasizes the importance of identifying cognitive development levels of students in grades 7 and 8 to teach properly to the existing skill level.

Toepfer[36] states that experimental studies, not yet published, now provide the testing and validation of these implications: cognitive growth of youngsters during the age 12 to 14 year period is dramatically increased when classroom learning is organized to teach new facts within the profile of thinking skills initiated during the age 10 to 12 year period. Youngsters during age 12 to 14 years can both learn new facts and mature and refine existing thinking skills more effectively than youngsters who are challenged to move on to higher level thinking skills at a similar age. The publishing of these findings should also confirm that it is poor judgement to try to force movement to higher level thinking skills for the majority of youngsters between age 12 and 14 years. Cognitive level testing can identify those youngsters who individually possess such readiness and can be successfully challenged to initiate new and higher level thinking competence. The publication of these findings and continued research in this area should provide middle grade educators with an important area of data for re-thinking existing pedagogic practice.

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[35] Epstein, op. cit.

[36] Conrad F. Toepfer, Jr., "What We Know: Reactions," Perspectives on Middle School Research, ed. Christina K. McCann (Cincinnati, Ohio: University of Cincinnati, 1980), p. 30.

Elkind[37] reports that some low socio-economic adolescents having to deal with everyday realities of survival have little opportunity to move to a cognitive level which deals with abstraction. They may, however, have developed alternative elaborations which educators have failed to recognize. Such students may have developed to the formal operational level in their own language, in coping with their own culture; however, because this appears to diverge from white middle class standards, it is not recognized by teachers and researchers.

Current Science Instruction for Early Adolescents

At the intermediate grades in the mid 1950's, science instruction was largely textbook based. Emphasis was on learning facts, and texts were used to cover a large body of content. In the early 1970's, there was a tendency to reduce the amount of content to allow for more in-depth treatment of the material, less reliance on the text, more "hands on" science and better content organization. Helgeson et al.[38] state that a greater variety of materials came into use. Current concerns such as "pollution, natural resources, and energy" received more attention in recent curricula, as did the concepts and processes of science, attitudes toward science, and laboratory experience.

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[37] Elkind, op. cit.

[38] S. L. Helgeson, P. E. Blosser, and R. W. Howe, Science Education: A Literature Review and Analysis Related to Assessment of Needs and Existing Practices in U.S. Schools in Pre-College Natural Science, Mathematics,

More recent data on the actual degree of utilization of various materials in the classroom are difficult to obtain. However, there are some indications of a trend in the past two or three years back toward greater reliance on the text, more factual content, and less "hands on" science. Stake and Easley[39] suggest that, due to increasing concern for basic skills and/or due to financial constraints, a shift toward more reading, and less laboratory experience and fewer field trips characterizes recent junior high school instruction. Stake has also suggested expense, discipline problems, and emphasis on tested outcomes as factors contributing to a general reduction in laboratory work.

It is interesting to note, however, that according to the Research Triangle Institute[40] report, 40 percent of

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and Social Science Education (NSF-76-20627) (Columbus, Ohio: Center for Science and Mathematics Education, The Ohio State University, September, 1977).

[39] R. Stake and J. Easley, Case Studies in Science Education (Champaign, Illinois: Center for Instructional Research and Curriculum Evolution and Committee on Culture and Cognition, University of Illinois at Urbana-Champaign, January, 1978).

[40] RTI (Research Triangle Institute), Report of the 1977 National Survey of Science, Mathematics, and Social

grade 7 through 9 science teachers considered inadequate student reading ability a serious problem.

Ayers and Price,[41] Bohardt,[42] and Randall[43] report a decline in the attitude of junior high/middle school students toward science. Beginning at about grade 6, students' positive attitudes toward science diminish, and this trend continues through the junior high years.

The overall decline in early adolescents' attitudes toward science is critical. Each of the three studies cited above reports this decline and, taken together, they provide evidence of a phenomenon worthy of further investigation.

Science Curricula for Early Adolescents

Relatively few available curricula in science are focused specifically on the period of early adolescence.

Studies Education (Research Triangle Park, N.C.: Author, 1977).

[41] J. B. Ayers and C. O. Price, "Children's Attitudes Toward Science," School Science and Mathematics, Vol. 75, No. 4, 1975, 311-318.

[42] P. C. Bohardt, "Attitudes Toward Process-Based Science Instruction Held by Students and Teachers in Grades Four Through Eight" (PhD dissertation, University of Arizona, 1974), Dissertation Abstracts International, Vol. 35, 1975, 7631A (University Microfilms No. 75-11909).

[43] R. E. Randall, Sr., "A Study of the Perceptions and Attitudes of Secondary School Students Toward Science as a School Subject, Science Content, and Science Teaching" (PhD dissertation, Columbia University, 1975), Dissertation

The rationale underlying science curricula for this age group is viewed on one hand as a capstone to elementary school science and on the other hand as preparing students for high school science.[44]

The 1978 Report of the National Science Foundation titled Early Adolescence: Perspectives and Recommendations, cited:

> No source was located which systematically surveyed the effectiveness of available middle/junior high school science, mathematics, or social science curricula.[45]

This statement resulted in the following recommendation:

> Information on the scope, suitability and effectiveness of existing curricula should be compiled.[46]

In a study of the Piagetian Model as directly applied to science subject matter, Lawson's[47] primary objective was an assessment of understanding of concrete and formal operational concepts by concrete and formal operational students in secondary school biology, chemistry and physics classes.

Abstracts International, Vol. 35, 1975, 5132A (University Microfilms No. 75-03177).

[44] Paul Dehart Hind, "Early Adolescence and the Science Curricula," Early Adolescence: Perspectives and Recommendations (Washington, D.C.: The National Science Foundation, 1978), p. 56.

[45] National Science Foundation, Early Adolescence: Perspectives and Recommendations, p. 180.

[46] Ibid., p. 181.

[47] Anton E. Lawson, "A Study of the Piagetian Model as Directly Applied to Science Subject Matter," in John W.

To accomplish this objective, the percentages of concrete and formal operational students in selected biology, chemistry, and physics classes were determined, and individual subjects were identified as concrete- or formal-operational thinkers. Six Piagetian-styled tasks were used to assess levels of thinking. The major concepts taught during the year in each science class were classified as concrete or formal operational, and written tests involving those concepts were constructed and administered.

Renner and Grant[48] in a recent study analyzed secondary school science textbooks, identifying concepts as being either major or minor and then classifying each concept within the two groups as being concrete or formal. In this work the researchers employed Lawson's[49] description of concrete concepts as those "whose meaning can be developed from first-hand experience with objects or events." Formal concepts are described as those "whose meanings are derived through position within a postulatory-deductive system." Formal concepts demand that those using them be able to reason from propositions, assumptions, and postulates; their understanding demands "If . . . ,

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Renner et al., Research, Teaching and Learning with the Piagetian Model (Norman: University of Oklahoma Press, 1976), pp. 140-173.

[48] John W. Renner and Rosalie Grant, "Can Students Grasp Physics Concepts?" The Science Teacher, Vol. 45, No. 7, October 1978, pp. 24-28.

[49] Lawson, op. cit., p. 144.

then . . . , therefore . . ." reasoning. Students who are not capable of formal reasoning cannot understand formal concepts.

This study sought to answer the following questions: What are the levels of intellectual development of selected students in biology, chemistry, and physics classes as determined by Piagetian tasks? What are the relationships between students' scores on the Piagetian tasks and written test scores on concrete- and formal-operational concepts; in other words, are concrete-operational students able to understand only concrete concepts while formal-operational students are able to understand both concrete- and formal-operational concepts?

The data indicate that approximately 64.8 percent of the biology students interviewed were operating entirely or partly at the concrete level. The chemistry subjects were best characterized as transitional thinkers with 92 percent of those interviewed categorized above concrete operational and below fully formal operational. The physics sample also consisted largely of students operating somewhere between fully concrete and fully formal operational.

Approximately 85 percent scored above concrete and below formal. Only 4.8 percent of the entire sample of 134 students interviewed were judged to be fully formal thinkers.

Major concepts taught during the year in the respective classes were isolated and categorized as concrete or formal. This was a significant step in that such a classification scheme had not been attempted previously. Most of the concepts taught in the three science disciplines were categorized as formal.

Subjects categorized as transition to concrete operational demonstrated understanding of neither concrete- nor formal-operational concepts. Subjects categorized as concrete demonstrated understanding of approximately 30 percent of the concrete-operational concepts; however, they demonstrated no understanding of formal-operational concepts. Not until the post concrete category was any understanding of formal concepts apparent. The subjects in formal categories demonstrated understanding of both concrete and formal concepts.

The results of this study indicate that a substantial portion of the secondary school science subject matter is not suitable in terms of the intellectual level of the learner.

The researcher recommends a careful re-evaluation of the major content of science courses in an attempt better to fit content to the level of the learner.

Six physics textbooks were analyzed and found to contain a total of 130 major concepts, all of which were classified as formal. Five of the textbooks were on the Oklahoma State Adapted Textbook list.

Data were obtained from a sample of 708 eleventh- and twelfth-graders from 13 Oklahoma secondary schools.

(The principals of those schools were asked to provide a random sample of students in those grades.)

Of the 708 students, 54 (8 percent) had completed or were currently enrolled in physics. Of these, 8 were eleventh-graders (15 percent) and 46 were twelfth-graders (85 percent). The "potential physics" group or those students who elect not to study physics consisted of 654 students, 409 eleventh-graders (63 percent) and 245 twelfth-graders (37 percent).

The results of the study indicated that since all the major concepts found in the physics texts examined were formal, understanding them presents some problem to the entire physics population--which exhibited formal thought 74.1 percent of the time. For students who elect not to take physics--the "potential physics" group, which used formal thought 42.7 percent of the time--the concepts were largely incomprehensible.

Discussion of the Research

The research reviewed indicates that the majority of early adolescents and young adults function at the concrete operational level and not at the formal operational level in understanding a great deal of the science subject matter taught at the secondary school level.

Perhaps this reflects poor science backgrounds on the part of the students, although this issue is not discussed by any of the researchers cited. It would be of considerable interest to know to what kinds of instructional materials the students were exposed, particularly in terms of readability levels and levels of concept development.

This review of research is suggestive but not conclusive that there is a significant relationship between scholastic grades in science and the ability of students to perform formal operational tasks. The majority of studies tend to focus on high school and college level students. A computer search (ERIC and Psychological Abstracts) indicates that few studies have focused on early adolescent students, in regard to the question being investigated.

The studies reviewed tended to give incomplete descriptions of the sample studies. The researchers give proportions of students at various grade levels that might be expected to operate at concrete and formal operational levels but neglect to describe the cultural and socio-economic backgrounds of the students. These factors tend to be related to varying performances on Piagetian tasks.

This review of research has revealed another issue requiring further investigation and research: To what extent do the objectives of science instruction (operationally defined by test items) require subjects to function at the level of formal operations?

In summary, most early adolescents and young adults do not appear to have attained the formal operational stage of cognitive development. There seems to be a large percentage of concrete operational individuals in the various age groups studied. It is therefore conceivable that few ninth-grade students have reached the formal operational level.

The present study sought to gather data on a practical testing of hypotheses suggested by the research reviewed in this chapter: when early adolescent students are presented with curriculum material appropriately written at their cognitive level their scholastic test scores will improve significantly. This study was designed to assist in the planning of curricula for students in junior high or middle schools.

CHAPTER 4

PROCEDURES FOR THE STUDY

Selection of the Sample

Permission for implementation of this study in a selected junior high school was granted by the district superintendent of schools. Permission was also obtained from Dr. John Renner, Director of the Cognitive Analysis Project, for use of the CAP Incidents. Following receipt of permission to implement the study, the researcher met with the school principal, the guidance counsellor, and two classroom teachers to provide only the essential information needed to assist in the study.

The population of the study consisted of 133 ninth-grade students, the total ninth-grade population of a junior high school in New Brunswick, Canada. This school was selected not only because the student population was viewed as comparable to other student populations in the province but primarily due to the interest the school staff and administration expressed in the study.

A description of the student population is presented in a letter from the school principal included in the appendix.

The students were heterogeneously grouped in five classes. The population included 61 males and 72 females with ages ranging from 159 months (13.25 years) to 228 months (19.00 years).

Data Collection

In January, 1979, the researcher administered the Group Embedded Figures Test (GEFT) and the Cognitive Analysis Project (CAP) Incidents to 133 ninth-grade students. The instruments are described in the next section of this chapter.

In each class the testing was done in the required ninth-grade Science classes to which students were assigned heterogeneously. For each class the researcher arranged a morning testing time with teachers who did not see the test instruments until the time of administration.

Students received an explanation of the differences which exist in the thinking and problem solving processes. They were told that most important in answering the CAP Incidents was expressing how they perceived their responses, rather than whether or not their responses were correct. Class periods were regularly scheduled laboratory sessions of 80 minutes in duration; the GEFT took 15 minutes to explain and administer. Most students completed the CAP Incidents within 30 minutes.

Both the GEFT and the CAP Incidents were hand-scored by the researcher. A sample of 25 sets of the CAP Incidents was also scored by a former participant in the original CAP project who had been trained in scoring. This was done to insure inter-rater agreement. A Pearson Product Moment Correlation of .885 was found with a significance of .001 between the two sets of scores.

The CAP Incidents and the Group Embedded Figures Test were scored, and each score was placed into a regression equation to derive a score which would indicate the level of cognitive development for each student as correlated with an entire Piagetian task interview. These scores were then categorized by cognitive level, age in months, and sex.

Following the review of the results from the GEFT and CAP instruments, three classroom groups were designated experimental and two were designated as comparison. Each group consisted of a representation of students who may be identified as concrete, transitional, and formal operational as indicated in Tables 1 and 2. The teacher with three classes had two experimental groups and one comparison group, whereas the teacher with two classes had one group of each. A *t*-test determined the difference between cognitive level scores for comparison and experimental groups.

The general conceptual or operational level of the textual material taught was categorized, as being concrete or formal operational, by a panel of experts in the field of science education, from a Piagetian perspective. The panel approach was selected because no validated instrument

Table 1

Distribution of Assigned Groups of Teacher 1

Cognitive Level	Group Assignment			
	Experimental Group 9B	Experimental Group 9E	Comparison Group 9D	Total No. in Each Level
Concrete Operational	17	20	17	54
Transitional	9	6	10	25
Formal Operational	0	0	1	1
Total No. in Each Class	26	26	28	80

Table 2

Distribution of Assigned Groups of Teacher 2

Cognitive Level	Group Assignment		
	Experimental Group 9C	Comparison Group 9A	Total No. in Each Level
Concrete Operational	12	18	30
Transitional	12	10	22
Formal Operational	1	0	1
Total No. in Each Class	25	28	53

exists which could be used to assess a curriculum unit as being written at a concrete or formal operational level.

A panel of three was selected on the basis of their recognition as experts in the field of Piagetian studies. Each of the panel members was asked to analyze specific chapters in two selected science texts and to categorize each chapter as either consisting of more concrete operational concepts or more formal operational concepts.

Although no specific criteria were applied to the curriculum units, each member of the panel tended to refer to a list[1] indicating the relationships between concrete and formal concepts which were found in five physics texts and reported in an article by Renner and Grant.[2]

The specific curriculum unit selected for analysis was Temperature and Heat, a physical science topic. The texts selected included Physical Science: A Modern Approach,[3] a student text used in ninth-grade Science classes in New Brunswick, and Exploring Matter and Energy,[4] also a student text, being considered as a replacement for the former text by the Curriculum Development Advisory

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[1] Renner and Grant, "Identification of Concrete Operational Concepts and Related Formal Operational Concepts."

[2] Renner and Grant, "Can Students Grasp Physics Concepts?"

[3] Bickell et al., op. cit.

[4] Blecha et al., op. cit.

Committee on Science Education. The chapter dealing with Temperature and Heat, in each book, presented similar concepts.

There was general agreement among the panel that the curriculum unit in Physical Science: A Modern Approach was more formal operational in nature, whereas the curriculum unit in Exploring Matter and Energy contained more concrete operational concepts. The latter text was used with three experimental groups and the former text with two comparison groups.

The researcher applied the Fog and Dale-Chall Readability Formulae to both texts and to the curriculum unit, Temperature and Heat, within each of the two texts.

The teachers, who were not aware of the specific purpose of the study, taught from the respective curriculum units during the months of April and May, 1979. At the end of the instructional period both teachers administered objective tests. Each teacher scored the tests and recorded the students' scores.

The scores on three previous science units were also obtained from the teachers' records reflecting scholastic achievement on two physical science units and one biology unit. A *t*-test was applied to determine the significance of difference between scholastic test scores from the three previous science curriculum units for the comparison and experimental groups.

Statistical tests were applied to test the five hypotheses. A *t*-test was applied to determine the significance of difference between scholastic test scores of concrete operational students on concrete and formal operational curriculum units, respectively. A *t*-test determined the significance of difference between scholastic test scores of transitional and formal operational students on concrete and formal operational curriculum units, respectively. Paired *t*-tests were applied to determine the significance of difference between the scholastic test scores from previous curriculum units for the Experimental and Comparison Groups and their scholastic test scores on assigned curriculum units.

A cross-tabulation of cognitive levels by sex was applied to determine the relationship between the scores of males and females.

Description of the Instruments

Group Embedded Figures Test

The GEFT is a non-verbal, perceptual test in which the subject attempts to identify a previously seen figure which is embedded within a larger complex figure. The test determines the perceptual field dependence-independence of the subject;

> persons who have difficulty disembedding simple figures from complex designs in the EFT tend to do less well in solving that class of problems which requires isolating

> an essential element from the context in which it is presented and using it in a different context.[5]

GEFT is based on the premise that persons who cannot perceive a problem are less likely to solve the problem.

The Cognitive Analysis Project recommends using the GEFT with three of the CAP Incidents to derive a score which would correlate most significantly with a Piagetian Task Interview score. "Data exist, which demonstrate that the cognitive characteristic the CAP was considering falls into the general area of perceptual field dependence-independence."[6]

A number of studies cited in the Examiner's Manual of the EFT supports the concept that the EFT is a test of field dependence-independence in perception which indicates the extent of competence at disembedding in intellectual functioning as well.[7]

The GEFT consists of one practice section with seven items and two additional sections of nine items each. Evidence indicates that it is "a satisfactory substitute

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[5] H. Witkin, P. Oltman, E. Roskin, and S. Karp. A Manual for the Embedded Figure Test (Palo Alto, California: Consulting Psychologists Press, 1971). The Group Embedded Figures Test, a variation of the EFT, is designed for administration to a group rather than to an individual.

[6] John W. Renner, "Evaluating Intellectual Development Using Written Responses to Selected Science Problems," Report to the National Science Foundation on Grant Number EPP75-19596, "Analysis of Cognitive Processes," University of Oklahoma, 1977, p. 122.

[7] Witkin, op. cit., p. 18.

[for the EFT] in research requiring group testing."[8] A Spearman-Brown prophecy formula produced a reliability estimate of .82.

Cognitive Analysis Project Incidents

CAP Incidents[9] (Appendix B) are written problems which attempt to elicit responses reflecting the use of formal reasoning patterns. Formal reasoning, according to Piaget and Inhelder,[10] requires an ability to separate and control variables, use proportional reasoning, and use combined logic.

Each student in Phase I of the CAP project was tested on the elements of reasoning in a one-to-one Piagetian task interview in which the student completed an observed "hands on" task. The written incidents were developed to provide a group-administered written instrument which would provide information about a student's level of reasoning that would be comparable to the one-to-one Piagetian task interview.

The reading levels of the incidents also had to be carefully controlled. While developing the incidents, the

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[8] Ibid., p. 28.

[9] Renner, op. cit.

[10] Bärbel Inhelder and Jean Piaget, The Growth of Logical Thinking from Childhood to Adolescence, trans. A. Parsons and S. Seagrin (New York: Basic Books, Inc., Publishers, 1958).

CAP used words from the Harris-Jacobson Basic Elementary Reading Vocabulary List[11] which had been found in three or more basal reading series used in grades 6 and below. Sentences of minimum length were also used.

The reading level of each incident was determined by a computer analysis supervised by Professor Milton D. Jackson, University of Virginia, using both the Harris-Jacobson scale and the Dale-Chall Formula for Predicting Readability.[12] The results of those computer analyses are shown in Table 3.

Table 3

Readability of CAP Incidents

Incidents	Harris-Jacobson	Dale-Chall
Shadows	4.77	6.14
Frogs	5.94	5.98
Geraniums	6.74	6.58

Correlations were made between scores on the entire Piagetian Task Interview and each CAP developed incident, and combinations of the seven incidents found to meet the criteria of the project for 295 subjects in grades 10, 11 and 12.

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[11] Albert J. Harris and Milton D. Jacobson, Basic Elementary Reading Vocabularies (New York: Macmillan, 1972).

[12] Edgar Dale and Jeanne S. Chall, "A Formula for Predicting Readability," Education Research Bulletin, Vol. 27, January 21, 1947, 11-20, 28.

A multiple regression equation developed by the Cognitive Analysis Project utilizing three incidents and the Embedded Figures Test resulted in a correlation of .70 and a standard error of 1.85. The equation providing the highest correlation with the entire Piagetian Interview included three incidents titled Shadows (S), Frogs (F), and Geraniums (G).

The weighted scores on these incidents and the GEFT, including the constant, constitute the equation (Renner, 1977):

$$E1 = 0.17\ (EFT) + 0.38\ (S) + 0.37\ (F) + 0.30\ (G) + 3.95$$

This equation was used in this study. Scoring of the CAP Incidents is based on a seven point set of criteria (Appendix B) which indicates gradations of reasoning as follows:

Scores	4 - 8	concrete operational
Scores	9 - 11	transitional
Scores	12 - 14	formal operational

The readability of the CAP incidents is based on the Piagetian Task Interview. Applying the Coefficient Alpha formula to determine the internal consistency of the three separate CAP incidents and the GEFT, Alpha = .723.

Experimental Group Test

The test prepared by the two teachers for the Experimental Group was based on Chapter 7, "Heat, Temperature, and Matter," of the text *Exploring Matter and Energy*. This curriculum unit was categorized as being predominantly concrete operational by the panel of experts.

Comparison Group Test

The test prepared by the two teachers for the Comparison Group was based on Chapter 9, "Temperature and Heat," of the text *Physical Science: A Modern Approach*. This curriculum unit was categorized as being predominantly formal operational by the panel of experts.

CHAPTER 5

ANALYSIS AND INTERPRETATION OF DATA

Following the administration and scoring of the tests described in Chapter 4, the collected data were subjected to computer analysis to test each hypothesis. This chapter begins with a data analysis for the sample and the comparison and experimental groups, and then discusses the basis for acceptance or rejection of each of the null hypotheses.

Data Analysis for Sample and Groups

The CAP incidents and the Group Embedded Figures Tests were scored, and each score was placed into a regression equation to derive a score which would indicate the level of cognitive development of each student as correlated with an entire Piagetian task interview. Table 4 presents the cognitive levels and age ranges for the sample. It is significant that 63.2 percent of this sample of ninth-graders are categorized as being concrete operational and that an additional 35.2 percent are considered to be at a transitional level of reasoning. It is anticipated that these students could experience difficulty when exposed to a provincially prescribed curriculum determined by a panel of experts in the field of Piagetian studies to be formal operational.

Table 4

Cognitive Levels and Age Ranges for Sample

Cognitive Level	Scores Range	Number of Students	Percent	Age Range in Months
Concrete	4 - 8	84	63.2	168 - 228
Transitional	9 - 11	47	35.3	169 - 212
Formal	12 - 14	2	1.5	159 - 166

A more detailed cognitive level score distribution is presented in Table 5. Tables 6 and 7, respectively, present the cognitive level distribution of the experimental and comparison groups' assignments.

Table 8 presents a distribution by sex and cognitive level for the experimental and comparison groups.

A *t*-test was applied to determine the difference between cognitive level scores for the comparison and experimental groups. A *t*-value of -0.78 was obtained (see Table 9). This value indicated that the difference between the cognitive level scores of the two groups was not statistically significant.

A *t*-test was applied to determine the significance of difference between scholastic test scores from three previous science curriculum units for the comparison and experimental groups. A *t*-value of 1.16 was obtained (see Table 10). This value indicated that the difference between the scholastic test scores from three previous science curriculum units of the two groups was not statistically significant.

On the basis of the above data, it was determined that the comparison and experimental groups were somewhat comparable.

The researcher applied the Fog and Dale-Chall Readability Formulae to both texts and to the curriculum unit, Temperature and Heat, within each of the two texts.

Table 5

Cognitive Level Score Distribution

Cognitive Scores	Absolute Frequency	Relative Frequency (%)	Cumulative Adjusted Frequency (%)
Concrete:			
5	1	0.8	0.8
6	15	11.3	12.0
7	29	21.8	33.8
8	39	29.3	63.2
Transitional:			
9	24	18.0	81.2
10	16	12.0	93.2
11	7	5.3	98.5
Formal:			
12	2	1.5	100.0
Total	133	100.0	

Mean	8.173	Std. Error	0.126	Median	8.051
Mode	8.000	Std. Dev.	1.449	Variance	2.099
Kurtosis	-0.268	Skewness	0.376	Range	7.000
Minimum	5.000	Maximum	12.000		

Table 6

Distribution of Experimental Group Assignment

Cognitive Level	Experimental Group Assignment			
	Class 9B	Class 9C	Class 9E	Total No. in Each Level
Concrete Operational	17	12	20	49
Transitional	9	12	6	27
Formal Operational	0	1	0	1
Total No. in Each Class	26	25	26	77

Table 7

Distribution of Comparison Group Assignment

Cognitive Level	Comparison Group Assignment		
	Class 9A	Class 9D	Total No. in Each Level
Concrete Operational	18	17	35
Transitional	10	10	20
Formal Operational	0	1	1
Total No. in Each Class	28	28	56

Table 8

Distribution by Sex

Comparison Group								
Class	Concrete Operational		Transitional		Formal Operational		Class Total	
	Male	Female	Male	Female	Male	Female	Male	Female
9A	8	10	5	5	0	0	13	13
9D	8	9	4	6	1	0	13	15
Total	16	19	9	11	1	0	26	30

Experimental Group								
Class	Concrete Operational		Transitional		Formal Operational		Class Total	
	Male	Female	Male	Female	Male	Female	Male	Female
9B	6	11	6	3	0	0	12	14
9C	5	7	5	7	1	0	11	14
9E	8	12	4	2	0	0	12	14
Total	19	30	15	12	1	0	35	42

Table 9

T-Test Results Determining Difference Between Cognitive Level Scores for Comparison and Experimental Groups

Variable	No. of Cases	Mean	Std. Dev.	Std. Error	T Value	Degrees of Freedom	2-Tail Prob.
Cognitive Level Score							
Comp. Group	56	8.5504	1.422	0.190	-0.78	131	0.438
Exp. Group	77	8.7433	1.417	0.161			

Table 10

T-Test Results Determining Difference Between Scholastic Test Scores from Three Previous Science Curriculum Units For Comparison And Experimental Groups

Variable	No. of Cases	Mean	Std. Dev.	Std. Error	T Value	Degrees of Freedom	2-Tail Prob.
Three Previous Science Test Scores							
Comp. Group	56	190.5000	67.971	9.083	1.16	131	0.250
Exp. Group	77	177.4675	61.281	6.984			

The results presented in Table 11 indicate that the text determined by the panel to be more formal operational had a higher readability level than did the text determined by the panel to be more concrete operational.

Hypothesis 1

> There is no significant difference between scholastic test scores of concrete operational students of Comparison and Experimental Groups on assigned curriculum units.

The researcher hypothesized that the test scores of concrete operational students in the Experimental Group would be higher on a curriculum unit assessed as being predominantly concrete operational than the test scores of students of a similar conceptual level in the Comparison Group who were tested on a curriculum unit assessed as being predominantly formal operational.

The Experimental Group test consisted of 25 objective questions each valued at one. The score was then multiplied by four to give a value based on 100. The Comparison Group test consisted of 10 objective questions, some with several parts. The test was valued at 100.

A *t*-test was applied to the scholastic test scores of concrete operational students from both the Comparison and Experimental Groups on assigned curriculum units. A *t*-value of -5.09 was obtained (see Table 12). This value indicated that the difference between the test scores of

Table 11

Readability of Curriculum Units

Curriculum Units	Fog	Dale-Chall
Physical Science: A Modern Approach		
Text	10.9	12.9
Chapter	10.9	12.6
Exploring Matter and Energy		
Text	7.1	8.7
Chapter	6.1	8.5

Table 12

T-Test Results Determining Difference Between
Test Scores of Concrete Operational Students
of Comparison and Experimental Groups
on Assigned Curriculum Units

Variable	No. of Cases	Mean	Std. Dev.	Std. Error	T Value	Degrees of Freedom	2-Tail Prob.
Test on Assigned Curriculum Unit							
Comp. Group	33	54.8485	16.417	2.858	-5.09	79	0.000
Exp. Group	48	74.0000	16.769	2.420			

the two groups was significant at the .01 level of confidence. Because the scores of the two groups differed more than could have occurred by chance, hypothesis 1 was rejected.

The concrete operational students in the Experimental Group achieved higher test scores on a curriculum unit assessed as being predominantly concrete operational than did students of a similar conceptual level in the Comparison Group who were tested on a curriculum unit assessed as being predominantly formal operational.

Hypothesis 2

> There is no significant difference between scholastic test scores of transitional and formal operational students of Comparison and Experimental Groups on assigned curriculum work.

The researcher hypothesized that the test scores of transitional and formal operational students in the Experimental Group would be comparable on a curriculum unit assessed as being predominantly concrete operational to the test scores of students of similar conceptual levels in the Comparison Group who were tested on a curriculum unit assessed as being predominantly formal operational.

A *t*-test was applied to the scholastic test scores of transitional and formal operational students from both the Comparison and Experimental Groups on assigned curriculum units. A *t*-value of -2.71 was obtained as indicated in Table 13. This value indicated that the difference between the test scores of the two groups was significant at the .05 level of confidence. Because the scores of the two groups differed more than could have occurred by chance, hypothesis 2 was rejected.

The transitional and formal operational students in the Experimental Group achieved higher test scores on a curriculum unit assessed as being predominantly concrete operational than did students of a similar conceptual level in the Comparison Group who were tested on a curriculum unit assessed as being predominantly formal operational.

Hypothesis 3

> There is no significant difference between scholastic test scores on previous curriculum units for Experimental Group students and their scholastic test scores on the curriculum unit assessed as being predominantly concrete operational.

The researcher hypothesized that students in the Experimental Group would attain higher test scores on the curriculum unit assessed as being concrete operational than on test scores from previous curriculum units which were taken from the prescribed text and assessed as being predominantly formal operational.

A paired *t*-test was applied to the scholastic test scores of students in the Experimental Group from three previous curriculum units and their scholastic test scores

Table 13

T-Test Results Determining Difference Between
Test Scores of Transitional and Formal
Operational Students of Comparison
and Experimental Groups on
Assigned Curriculum Units

Variable	No. of Cases	Mean	Std. Dev.	Std. Error	T Value	Degrees of Freedom	2-Tail Prob.
Test on Assigned Curriculum Unit							
Comp. Group	21	70.0000	23.875	5.210	-2.71	30.70	0.011
Exp. Group	27	85.9259	14.180	2.729			

on the assigned curriculum unit. Table 14 presents t-values of -12.64; -8.72; and -6.92 respectively for the previous curriculum units of Physics 1, Physics 2 and Biology.

These values indicated that the differences between the previous test scores and the test scores attained on the assigned curriculum unit were significant at the .01 level of confidence. Because the scores of the previous curriculum units and the assigned curriculum unit differed more than could have occurred by chance, hypothesis 3 was rejected.

The students of the Experimental Group attained higher test scores on the curriculum unit assessed as being concrete operational than on either of the three previous curriculum units. The three previous curriculum units were from the prescribed text assessed as being predominantly formal operational.

Hypothesis 4

> There is no significant difference between scholastic test scores on previous curriculum units of Comparison Group students and their scholastic test scores on the curriculum unit assessed as being predominantly formal operational.

The researcher hypothesized that students in the Comparison Group would attain comparable test scores on the curriculum unit assessed as being formal operational to test scores attained on previous curriculum units which were

Table 14

Experimental Group Paired T-Test Results Determining Difference Between Previous Science Test Scores and Scores on Experimental Test

Variable	No. of Cases	Mean	Std. Dev.	Std. Error	T Value	Degrees of Freedom	2-Tail Prob.
Physics 1	75	56.7333	19.748	2.280	-12.64	74	0.000
Exp. Test		78.3200	16.843	1.945			
Physics 2	74	60.4323	21.863	2.541	- 8.72	73	0.000
Exp. Test		78.3514	16.956	1.971			
Biology	75	61.8000	24.542	2.834	- 6.92	74	0.000
Exp. Test		78.3200	16.843	1.945			

taken from the prescribed text and assessed as being predominantly formal operational.

A paired t-test was applied to the scholastic test scores of students in the Comparison Group from three previous curriculum units and their scholastic test scores on the assigned curriculum unit. Table 15 presents t-values of 2.72; 1.33; and 3.50 respectively for the previous curriculum units of Physics 1, Physics 2 and Biology.

These values indicated that the differences between the previous test scores and the test scores attained on the assigned curriculum unit were significant at the .05 level of confidence. Because the scores of the previous curriculum units and the assigned curriculum units differed more than could have occurred by chance, hypothesis 4 was rejected.

The students of the Comparison Group attained higher test scores on the three previous curriculum units than on the curriculum unit assessed as being formal operational. The three previous curriculum units were, however, from the prescribed text assessed as being predominantly formal operational.

Hypothesis 5

There is no signifcant difference between cognitive level scores of males and females.

Table 15

Comparison Group Paired T-Test Results Determining Difference Between Previous Science Test Scores and Scores on Comparison Test

Variable	No. of Cases	Mean	Std. Dev.	Std. Error	T Value	Degrees of Freedom	2-Tail Prob.
Physics 1	46	67.5652	20.625	3.041	2.72	45	0.009
Comp. Test		60.7609	25.504	3.760			
Physics 2	45	66.0667	22.094	3.294	1.33	44	0.189
Comp. Test		61.9333	24.506	3.653			
Biology	46	71.3913	22.442	3.309	3.50	45	0.001
Comp. Test		60.7609	25.504	3.760			

A Cross-Tabulation of Cognitive Levels by Sex was applied. A Chi-square statistic of 1.61830 with a significance of 0.2033 indicated that there is little relationship between sex and cognitive level.

Hypothesis 5 was accepted (see Table 16).

Table 16

Cross-Tabulation of Cognitive Levels by Sex

	Sex		
	Male	Female	Total
Concrete	35 57.4%	49 68.1%	84 63.2%
Transitional/Formal	26 42.6%	23 31.9%	49 36.8%
Total	61 45.9%	72 54.1%	133 100.0%

Chi square = 1.61830 1 Degree of freedom

Significance = 0.2033

CHAPTER 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

This study was designed to investigate differences between the cognitive developmental levels of early adolescents and scholastic scores derived from tests on curriculum written at concrete and formal operational levels.

The two major purposes of the study were to determine the cognitive levels of ninth-grade students, and to investigate differences between the scholastic test scores of concrete and formal operational students on predetermined curriculum units in science education, one of which emphasized concrete operational reasoning and the other, formal operational reasoning.

The study attempted to answer these questions:

1. Are ninth-grade students assessed in this study predominantly at the concrete, transitional or formal operational stage of intellectual development? Do they differ in this regard according to sex?

2. Are the percentages of ninth-grade students assessed in this study at the concrete, transitional and formal operation stages consistent with earlier studies?

3. Is there evidence of a discrepancy between the conceptual level of the prescribed curriculum and students' levels of operational thought?

4. When concrete operational students use textual material judged as requiring concrete operational thought, will they have higher scholastic test scores than students of a similar conceptual level who use textual material judged as requiring formal operational reasoning?

5. When transitional and formal operational students use textual material judged as requiring formal operational thought, will they have comparable scholastic test scores to students of similar conceptual levels who use textual material judged as requiring concrete operational reasoning?

The investigation took place in the Province of New Brunswick, Canada, during the 1978-1979 school year. The sample included 133 ninth-grade students, the total ninth-grade population, from a selected junior high school. The total sample included 61 males and 72 females.

During the last two weeks of January, 1979, the Group Embedded Figures Test (GEFT) and the Cognitive Analysis Project (CAP) Incidents were administered to the total population.

The scores derived from these tests, test scores on previous curriculum units, the ages of students, researcher-identified groupings, and panel-assessed curriculum units were analyzed to determine Chi-square values and *t*-values.

Summary of Findings

Hypothesis 1 stated that there would be no significant difference between scholastic test scores of concrete operational students of Comparison and Experimental Groups on assigned curriculum units. A *t*-test indicated a *t*-value of -5.09. This was significant at the .01 level of confidence. Thus, hypothesis 1 was rejected.

The concrete operational students in the Experimental Group achieved higher test scores on a curriculum unit assessed as being predominantly concrete operational than did students of a similar conceptual level in the Comparison Group who were tested on a curriculum unit assessed as being predominantly formal operational.

Hypothesis 2 stated that there would be no significant difference between scholastic test scores of transitional and formal operational students of Comparison and Experimental Groups on assigned curriculum units. A *t*-test indicated a *t*-value of -2.71. This was significant at the .05 level of confidence. Thus, hypothesis 2 was rejected.

The transitional and formal operational students in the Experimental Group achieved higher test scores on a curriculum unit assessed as being predominantly concrete operational than did students of a similar conceptual level in the Comparison Group who were tested on a curriculum unit assessed as being predominantly formal operational.

Hypothesis 3 stated that there would be no significant difference between scholastic test scores on previous curriculum units for Experimental Group students and their scholastic test scores on the curriculum unit assessed as being predominantly concrete operational. Paired *t*-tests indicated *t*-values of -12.64, -8.72, and -6.92 respectively for the previous curriculum units of Physics 1, Physics 2 and Biology. Each of the *t*-values was significant at the .01 level of confidence. Thus, hypothesis 3 was rejected.

The students of the Experimental Group attained higher test scores on the curriculum unit assessed as being concrete operational than on either of the three previous curriculum units. The three previous curriculum units were from the prescribed text assessed as being predominantly formal operational.

Hypothesis 4 stated that there would be no significant difference between scholastic test scores on previous curriculum units of Comparison Group students and their scholastic test scores on the curriculum unit assessed as being predominantly formal operational. Paired *t*-tests indicated *t*-values of 2.72, 1.33, and 3.50 respectively for the previous curriculum units of Physics 1, Physics 2 and Biology. Each of the *t*-values was significant at the .05 level of confidence. Thus, hypothesis 4 was rejected.

The students of the Comparison Group attained higher test scores on the three previous curriculum units than on the curriculum unit assessed as being formal operational. The three previous curriculum units were, however, from the prescribed text assessed as being predominantly formal operational.

Hypothesis 5 stated that there would be no significant difference between cognitive level scores of males and females.

A cross-tabulation of cognitive levels by sex indicated a Chi-square statistic of 1.61830 with a significance of 0.2033. This indicated that no relationship existed between sex and cognitive level. Hypothesis 5 was accepted.

Conclusions

This study began with give questions being postulated. The first question concerned the intellectual development level of ninth-grade students.

The ninth-grade sample investigated showed 63.2 percent of the students still largely at the concrete level of intellectual development, 35.3 percent at the transitional level, and only 1.5 percent assessed at a formal operational level. There was no significant relationship between sex and cognitive level.

The second question asked whether the percentages of students at the concrete, transitional and formal operational levels in this study were comparable to the percentages identified in earlier studies. There are, admittedly, few studies attempting to measure the cognitive levels of junior high and/or middle school students.

However, these findings did not contradict the findings of earlier studies which indicated that few students even in senior high school are formal operational (see Table 21 in Appendix, A Review of Piagetian Studies Relevant to Science Instruction at the Secondary and College Level).

The third questioned the appropriateness in terms of conceptual level of the prescribed curriculum for ninth-grade science students. The results of this investigation indicate that the curriculum unit designated as being predominantly formal operational in nature was less suitable in terms of the intellectual level of the learner than was the unit designated as being predominantly concrete operational.

Since the majority of students were found to be unable to develop an appreciable understanding of formal abstract concepts, it appears clear that, for them, a science course which is not grounded in concrete experience is less likely to teach them the desired concepts. Perhaps this conclusion should be tempered by stating that concrete operational thinkers did not develop expected understandings of formal concepts that were measured with the instruments employed in this investigation.

Piaget has said that the adolescent enters the formal period between eleven and twelve years of age[1] and reaches "an equilibrium point at about fourteen to fifteen years."[2]

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[1] Jean Piaget, Psychology of Intelligence (London, England: Routledge and Kegan Paul, 1950), p. 123.

The mean age of the ninth-grader in this study was 180.429 months (15.04 years). It was, however, determined that 63.2 percent of the ninth-grade students were still at the concrete operational level and an additional 35.3 percent were at the transitional level. Only 1.5 percent of the students were found to be at the formal operational level.

In addition, this study reported the expressed opinion of a panel of experts in the field of Piagetian Studies, which indicated that the prescribed science text used by all ninth-grade students was predominantly formal operational.

It would appear that the age ranges Piaget referred to in a discussion of formal operational reasoning did not apply to the ninth-grade students in this study.

On the mistaken assumption that a given level of ability has been reached, presentation of subject matter may be self-defeating if it is beyond the students' ability to grasp.

The fourth question asked whether concrete operational students would score higher on a test based on a curriculum unit requiring concrete operational thought than on a test based on a curriculum unit requiring formal operational thought.

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[2] Inhelder and Piaget, The Growth of Logical Thinking from Childhood to Adolescence, p. 335.

This investigation indicated that concrete operational students scored significantly higher on the test based on the curriculum unit assessed as being predominantly concrete operational than students of a similar conceptual level scored on the test based on the curriculum unit assessed as being predominantly formal operational.

Concrete operational students were not able to develop an understanding of abstract concepts; that is, concepts that require the building of theories and departures from concrete reality.

The final question asked whether students who are transitional and formal operational would attain comparable scores on tests based on curriculum units assessed as being concrete and formal operational, respectively.

This study indicates that transitional and formal operational students score significantly higher on a test based on a curriculum unit assessed as being predominantly concrete operational than on a test based on a curriculum unit assessed as being predominantly formal operational.

The indication is that formal thought does contribute to the understanding of concrete concepts.

Renner[3] states that formal thought contributes to the understanding of concrete concepts. He suggests two tentative explanations for this finding:

> 1. Formal operations may help in the understanding of concrete concepts by the elucidation of a more comprehensive system of both concrete and formal content. This larger frame-of-content reference allows the learner to see relationships involving concrete objects, situations, or events previously unrecognized. This expanded frame of reference thereby brings deeper meaning to concrete as well as formal content.
>
> 2. The teaching procedures used in the classrooms are largely expository; consequently, students seldom are confronted with first hand concrete experiences with any aspects of the discipline. These procedures, in effect, render potentially concrete material abstract or formal, and the learner does not, therefore, have the opportunity to develop understanding of it until he enters the formal stage.

It may be that there is yet another alternate conclusion. The students may not have to strive to the same extent in concrete operational experiences and may be more at ease even though they may be capable of formal operational thought.

It can be concluded that the curriculum unit designated as being predominantly formal operational in nature is less suitable in terms of the intellectual level of the learner. The ninth-grade sample investigated showed 63.2 percent of the students still largely at the concrete level of intellectual development. Both concrete and transitional/formal students scored significantly higher on a test based on the concrete operational curriculum unit than on a test based on the formal operational curriculum unit.

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[3] Renner et al., Research, Teaching, and Learning with the Piaget Model, pp. 170-171.

The intellectual level of the learner must become a major consideration in curriculum reform.

Recommendations

The following recommendations can be made as a result of this study.

1. A careful re-evaluation of the major content of science courses should be conducted in an effort to better fit the content to the reasoning level of the learner. Perhaps more important than major shifts in content matter is a careful evaluation of teaching procedures and sequencing of materials to help lead the learner from concrete to formal thinking patterns.

2. It is imperative that teachers responsible for the education of early adolescent learners not only be knowledgeable about the nature of the subject to be taught but must also be aware of the nature of the learner. This could be achieved through preservice and inservice teacher training. In terms of preservice, universities should offer courses in developmental psychology and methodology relating specifically to early adolescent learners. Inservice training should be made available to teachers of this age group concerning thought processes and the kinds of intellectual operations these students are capable of

performing. Teachers should also be made aware of recent trends and developments in education and in developmental psychology relative to early adolescent learners.

Piaget is more specific and perhaps this is the more responsible approach. He urges that teachers be child development specialists and that active methods be employed in their training. Rather than having teachers listen to lectures on child development, he advocates at least one year of clinical experience with children. This would not only involve administering classical Piagetian tasks to individual children, but also original research projects on children's thinking. Whereas the beginnings of the classical tasks have become almost standardized, the original research would focus on developing an ability to phrase questions to contact the thinking of different children. With this background in child development, teachers would be better prepared in areas of assessment, analysis of curricula, and classroom practice.[4]

Preservice and inservice education should provide meaningful experiences and opportunities for teachers to observe children in an effort to analyze levels of reasoning; to analyze textual materials in terms of cognitive level; to practice translating abstract material to concrete experiences and to practice in administering individual Piagetian tasks and the Incidents of the Cognitive Analysis Project including the Group Embedded Figures Test.

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[4] Milton Schwebel and Jane Raph, Piaget in the Classroom (New York: Basic Books, 1973).

3. Science education planning, coordination and development should be undertaken with due regard to the cognitive abilities of students. Determination of the child's reasoning level should be the basis for the design of curriculum and mode of instruction.

4. It is essential that flexibility be built into the science program so that different learners can operate, be active, and have experiences on different developmental levels. A modern curriculum should have the material to fulfill the objectives for the limited learners as well as for the average and bright at all cognitive levels. Curriculum planners should think more in terms of content-adjusted and process-adjusted curricula. In this way it would be possible to retain all the important concepts, and arrive at a more meaningful, practicable and strengthened program.

5. The incompleteness of formal operational abilities at the ninth-grade level indicates a need for research at higher age levels to trace its subsequent development.

6. There is a need for an analysis instrument or some means of assessment in addition to a panel of experts to determine the conceptual level of curricular material.

7. There is a need for research designed to investigate possible relationships between readability levels and levels of cognitive development. The curriculum materials available for use in this study were substantially different in readability levels.

8. There is a need for replications of this study and for other practical classroom-based research focusing on early adolescents in all subjects of the curriculum.

9. The ninth-grade science text prescribed for use in the public schools of New Brunswick, Canada, should be replaced by a text that contains more concrete operational concepts.

10. There is a need for research designed to determine teacher attitude in regard to curricular material.

APPENDIX A

TABLES

Table 17

Age Distribution of Subjects

Cognitive Scores	Absolute Frequency	Relative Frequency (%)	Cumulative Adjusted Frequency (%)
159	1	.8	.8
166	1	.8	1.5
168	1	.8	2.3
169	10	7.5	9.8
170	5	3.8	13.5
171	3	2.3	15.8
172	5	3.8	19.5
173	14	10.5	30.1
174	9	6.8	36.8
175	5	3.8	40.6
176	5	3.8	44.4
177	10	7.5	51.9
178	3	2.3	54.1
179	8	6.0	60.2
180	6	4.5	64.7
181	3	2.3	66.9
183	4	3.0	69.9
184	1	.8	70.7
185	3	2.3	72.9
186	5	3.8	76.7
187	2	1.5	78.2
188	2	1.5	79.7
189	2	1.5	81.2
190	1	.8	82.0
191	4	3.0	85.0
192	7	5.3	90.2
194	1	.8	91.0

Table 17--Continued

Cognitive Scores	Absolute Frequency	Relative Frequency (%)	Cumulative Adjusted Frequency (%)
197	1	.8	91.7
198	1	.8	92.5
199	3	2.3	94.7
204	1	.8	95.5
205	1	.8	96.2
207	1	.8	97.0
209	1	.8	97.7
211	1	.8	98.5
212	1	.8	99.2
228	1	.8	100.0
Total	133	100.0	

Mean	180.429	Std. Error	0.943	Median	177.250
Mode	173.000	Std. Dev.	10.870	Variance	118.155
Kurtosis	2.735	Skewness	1.432	Range	69.000
Minimum	159.000	Maximum	228.000		

Table 18

Age Distribution for Cognitive Level Scores 4-8 (Concrete)

Age in Months	Absolute Frequency	Relative Frequency (%)	Cumulative Adjusted Frequency (%)
168	1	1.2	1.2
169	3	3.6	4.8
170	3	3.6	8.3
171	2	2.4	10.7
172	4	4.8	15.5
173	6	7.1	22.6
174	7	8.3	31.0
175	2	2.4	33.3
176	3	3.6	36.9
177	5	6.0	42.9
178	3	3.6	46.4
179	7	8.3	54.8
180	2	2.4	57.1
181	3	3.6	60.7
183	3	3.6	64.3
184	1	1.2	65.5
185	2	2.4	67.9
186	4	4.8	72.6
187	2	2.4	75.0
188	2	2.4	77.4
189	1	1.2	78.6
190	1	1.2	79.8
191	3	3.6	83.3
192	4	4.8	88.1
194	1	1.2	89.3

Table 18--Continued

Age in Months	Absolute Frequency	Relative Frequency (%)	Cumulative Adjusted Frequency (%)
197	1	1.2	90.5
198	1	1.2	91.7
199	3	3.6	95.2
204	1	1.2	96.4
205	1	1.2	97.6
211	1	1.2	98.8
228	1	1.2	100.0
Total	84	100.0	

Mean	181.845	Std. Error	1.173	Median	178.929
Mode	174.000	Std. Dev.	10.750	Variance	115.554
Kurtosis	3.276	Skewness	1.485	Range	60.000
Minimum	168.000	Maximum	228.000		

Table 19

Age Distribution for Cognitive Level Scores 9-11 (Transitional)

Age in Months	Absolute Frequency	Relative Frequency (%)	Cumulative Adjusted Frequency (%)
169	7	14.9	14.9
170	2	4.3	19.1
171	1	2.1	21.3
172	1	2.1	23.4
173	8	17.0	40.4
174	2	4.3	44.7
175	3	6.4	51.1
176	2	4.3	55.3
177	5	10.6	66.0
179	1	2.1	68.1
180	4	8.5	76.6
183	1	2.1	78.7
185	1	2.1	80.9
186	1	2.1	83.0
189	1	2.1	85.1
191	1	2.1	87.2
192	3	6.4	93.6
207	1	2.1	95.7
209	1	2.1	97.9
212	1	2.1	100.0
Total	47	100.0	

Mean	178.660	Std. Error	1.524	Median	175.333
Mode	173.000	Std. Dev.	10.449	Variance	109.186
Kurtosis	2.923	Skewness	1.759	Range	43.000
Minimum	169.000	Maximum	212.000		

Table 20

Age Distribution for Cognitive Level Scores 12-14 (Formal)

Age in Months	Absolute Frequency	Relative Frequency (%)	Cumulative Adjusted Frequency (%)
159	1	50.0	50.0
166	1	50.0	100.0
Total	2	100.0	

Mean	162.500	Std. Error	3.500	Median	159.500
Mode	159.000	Std. Dev.	4.950	Variance	24.500
Range	7.000	Minimum	159.000	Maximum	166.000

Table 21

A Review of Piagetian Studies Relevant to Science Instruction at the Secondary and College Level

Studies of the Percentage of Subjects at Various Development Levels

STUDY			DEVELOPMENTAL LEVEL		
Researcher	Sample	Number of Tasks Used	Concrete %	Transitional %	Formal %
Nordland et al. (1974)	96 students age range 11.7-12.6	10	83.4	--	15.6
Renner and Stafford (1972)	298 students grades 7,8,9	6	77	13	6
Renner and Stafford (1972)	290 students grades 10,11, 12	6	66	17	14
Lawson and Blake (1974)	68 high school biol. students	3	47	--	53
Lawson (1974)	high school students 51 biology 50 chemistry 33 physics	5	 64.8 22 36.3	 -- -- --	 35.2 78 63.7

Table 21--Continued

STUDY			DEVELOPMENTAL LEVEL		
Researcher	Sample	Number of Tasks Used	Concrete %	Transitional %	Formal %
Nordland et al. (1974)	506 high school students	10	85.8	--	13.2
Chiappetta and Whitfield (1974)	high school seniors	3			
	26 vocational		61.5	--	38.5
	26 general		53.8	--	46.2
	26 college prep.		27		73
McKinnon and Renner (1971)	131 college freshmen	5	50	25	25
Lawson and Renner (1974)	143 college freshmen	5	51	27	22
Juraschek (1974)	college students	3			
	141 prospective elem. tea.		52	--	48
	19 math st. tea.		1	--	99
	11 honors cal. students		0	--	100

Table 22

Stages of Intellectual Development as Described by Piaget*

Stage of Development	Age Range
Sensorimotor - Learning through the senses and manipulation. Awareness that objects remain the same when viewed from different angles.	Birth to 2 years
Phase 1 Reflexes	Birth to 1 month
The newborn depends heavily on his reflexes for interaction with the environment. The infant profits from experience and actively modifies the reflex schemes.	
Phase 2 Primary Circulation Reactions	1 to 4 months
a) develops the primary circular reactions, b) learns in a primitive way to anticipate future events, c) the first signs of curiosity appear, d) sometimes repeats the behavior of models, e) lacks a mature object concept, but develops several patterns of behavior which are preliminary steps in the right direction. He coordinates the previously independent schemes of looking and hearing, among others. He shows passive expectancy by watching for a brief time the spot where an object has disappeared.	

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*Table form adapted from Ernest R. Hilbard and Richard C. Atkinson, Introduction to Psychology, 4th ed. (New York: Harcourt, Brace and World, 1968). The information presented in the table represents a synthesis of descriptions of Piaget's Theory of Intellectual Development cited in Robert F. Biehler, Psychology Applied to Teaching (Boston: Houghton Mifflin Company, 1971), p. 81;

Table 22--Continued

Stage of Development	Age Range
Phase 3 Secondary Circular Reactions	4 to 10 months
Behavior and interest extend beyond own body, makes more extensive, but still immature, contact with the external environment. a) develops secondary circular reactions, b) shows preliminary indications of classification or meaning, c) imitation is now more systematic and precise, d) considerable progress toward attainment of the object concept.	
Phase 4 Coordination of Secondary Schemata	10 to 12 months
Behavior is increasingly systematic and well organized. a) able to coordinate secondary schemes, b) by interacting with his environment, the infant learns something about relations of objects, c) ability to anticipate events which do not depend on his own actions, d) imitates the novel behavior of models, e) object concept almost fully developed.	
Phase 5 Tertiary Circular Reactions	12 to 18 months
Climax of sensorimotor period.	

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and Herbert Ginsburg and Sylvia Opper, *Piaget's Theory of Intellectual Development* (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1969), pp. 26-206.

Table 22--Continued

Stage of Development	Age Range
a) shows an active interest in producing new behavior and novel events, b) attempts to develop new means for dealing with obstacles rather than relying on previously successful schemes, c) increasingly adept at imitating new actions of models, d) can comprehend a complex series of displacements and search for the object in the proper place.	
Phase 6 Internalization of Sensorimotor Schemata	18 months to 2 years
a) transition to symbolic thought, b) imitate a model even though the latter may not be present, c) can reconstruct a series of invisible displacements of an object because of his new abilities in representation.	
Preoperational	
Preoperational Phase	2 to 4 years
Classification of things by a single feature (e.g., size). No concern about apparent contradictions (e.g., relationship between size and weight, as when a large light object floats, and a small heavy object sinks).	
a) extracting concepts from experiences; reality is what he perceives; there are no alternatives to him, b) rudimentary forms of language development at the age of two; the child develops	

Table 22--*Continued*

Stage of Development	Age Range
language skills by four to make it possible for him to communicate his thoughts.	
Intuitive Thought Phase	4 to 7 years
Intuitive (not really understood) classification. Gradual awareness of conservation of mass, weight, and volume (amount remains the same even if transferred to a container of different size and shape).	
a) judgment is still intuitive and subjective, but deals with somewhat more complex configurations than in previous stage, b) can make more systematic interrogations due to ability to manipulate experimental objects more effectively, c) accurate judgment is limited by three factors: i) is still dependent on sensory experiences, ii) does not consider two or more dimensions at the same time, iii) does not rearrange or reorganize information in his mind.	
Concrete Operations	7 to 11 years
Ability to think out problems previously "worked" out. Logical thought, e.g., genuine classification, learning to organize objects into a series; reversing operations (as in arithmetic).	
a) learns to master logical operations using material with a	

Table 22--Continued

Stage of Development	Age Range
concrete content, b) unable to think abstractly about a problem, c) an understanding of the principle of conservation leads directly to an awareness of reversibility, d) can use various approaches to the solution of a problem, e) concerned with the relationship of the parts of the whole. f) can perform the operation of serializing, g) language becomes primarily sociocentric while egocentric speech decreases, h) can comprehend the following four concrete operational groupings: i) combinativity ii) reversibility iii) associativity iv) identity or nullifiability	
Formal Operations Comprehension of abstract concepts, e.g., ability to form "ideas" and reason about the future, ability to handle contrary-to-fact propositions, and ability to develop and test hypotheses.	11 to 15 years
Substage III-A Appears to be a preparatory stage in which the adolescent may make correct discoveries and handle certain formal operations, but the approach is cumbersome and he is not yet able to provide systematic and rigorous proof.	11-12 to 14-15 years
Substage III-B The adolescent is capable of formulating more elegant	14-15 years onward

Table 22--Continued

Stage of Development	Age Range
generalizations and advancing more inclusive laws; most of all he is able to provide spontaneously more systematic proof, since he can use methods of control	
A higher degree of mastery of the formal operations; he has the ability to make logical combinations in the following ways: i) combine by conjunction ii) combine by disjunction iii) combine by implication iv) combine by incompatibility	

APPENDIX B

LETTER OF WAIVER, PANEL OF EXPERTS, LETTER DESCRIBING STUDENT POPULATION, CAP INCIDENTS AND SCORING CRITERIA

JAN 19 1979

The
University of Oklahoma 820 Van Vleet Oval Norman, Oklahoma 73019

College of Education

January 11, 1978

Mr. W. Barry Miller, Coordinator
Junior High School Education
Department of Education
Post Office Box 6000
Fredericton, New Brunswick
Canada

Dear Mr. Miller:

I presume by this time you have heard from Rosalie Grant relative to the questions that you asked about the article that appeared in The Science Teacher. I will not comment further on that.

You asked for permission to use the instrument developed by the Cognitive Analysis Project. You may consider this letter as giving you permission to do so. You also asked for permission to use the Embedded Figure Test. I cannot give you permission to do that because I do not own the copyright. I would, however, suggest that you contact the Consulting Psychologist Press, 577 College Avenue, Palo Alto, California, 94306.

Thank you for your interest in our work, and we look forward to hearing from you about the results of your study.

Best regards,

John W. Renner

John W. Renner
Professor of Science Education

JWR:mkw

PANEL OF EXPERTS

Dr. Herbert G. Cohen
Professor of Elementary Education
Arizona State University
Tempe, Arizona

Dr. Rosalie M. Grant
Associate Professor of Science Education
The University of Oklahoma
Norman, Oklahoma

Dr. Livingston S. Schneider
Project Evaluator
Lawrence Hall of Science
University of California
Berkeley, California

P O. Box 1180

390 Adelaide Street

Principal:
J. G. HANSON
B.T., B.Ed., M.Ed.

L. E. REINSBOROUGH SCHOOL
DALHOUSIE, N. B.
E0K 1B0

April 10, 1979.

Mr. B. Miller,
Junior High School Consultant,
Department of Education,
P. O. Box 6000,
Fredericton, N. B. E3B 5H1

Dear Mr. Miller:

Re your request for an overview of the student population of the L. E. Reinsborough School.

The student population of the L. E. Reinsborough School is derived from all areas of Restigouche County from Jacquet River to Dalhousie Junction. The communities consist of extremely small unincorporated areas such as Black Point which has approximately 6 homes and a population of 20 to the Town of Dalhousie, an industrial center and sea port, with in excess of 2000 homes and a population of approximately 5,000.

The students come from a variety of backgrounds -- from where one or both parents have a college education to that of neither parent having completed elementary school. These homes also offer the students a variety of resources; some providing an up-to-date library and an educational stimualting environment to others where the daily paper is a rarity and no interest is expressed in the value of education.

In comparison, our pupils come from environmental and educational backgrounds comparible to any student body in the province of New Brunswick.

Standardized educational testing programs were prevelent in District No.3 schools during the years 1969 through 1974. Educationally, our students produced scores on tests such as C.T.B.S., Gates Mac Ginitie Reading Tests and Stanford Achievement Tests (Reading and Math) which were compatible with a normal intelligence curve.

A standardized testing program has been reactivated in this school for the present school year and the results of same will be forwarded to you as they are available.

A sampling of the Gates Mac Ginitie Reading test is herewith enclosed.

I trust this answers your basic question.

Sincerely yours,

J. G. Hanson, Principal.

JGH/et
Encl.

SCHOOL ______________________________ GRADE ________

NAME (PRINT) ______________________________________

BIRTHDATE ____
(month) (day) (year)

MALE __________________ FEMALE __________________

NAME ______________________ SCHOOL __________________

The lengths of the shadow of a building and the shadow of a post are measured at the same time of day.

The building shadow's length is 50 meters.

The height of the post is 3 meters.

The post shadow's length is 2 meters.

How many meters tall is the building? Show your calculations. Write a paragraph to explain why you computed the height of the building the way you did.

NAME ______________________ SCHOOL ________________

An ecologist conducted an experiment to find out how many frogs lived in a pond. He could not catch all of the frogs and count them. The first day he caught 55 frogs and put a band on one of the legs of each frog. He waited a week to give the banded frogs a chance to distribute themselves evenly throughout the pond. He then caught 72 frogs, and 12 of them had bands on one leg.

Using all this information, what could the ecologist conclude about the number of frogs in the pond? Show any calculations you make, and then write a paragraph to explain how you arrived at your answer.

NAME ______________________ SCHOOL ________________

You have an unlimited supply of geranium plants. They are exactly alike. All are in the same kind of pots and have been planted in the same kind of soil. You are told that such factors as fertilizer, the amount of water, and the amount of sunlight affect the way the plants will grow. Describe the experiments you need to do in order to test whether or not each of those factors is important to the growth of geranium plants. Be sure to include reasons why you do the experiment the way you do.

CRITERIA FOR SCORING FROGS AND SHADOWS

Proportional Reasoning Scale: Final Version

1. No response. No mathematical attempt.

   Example: "I don't know," "I can't think of anything," or "I can't do it."

2. There is mathematical manipulation without a class inclusion concept, or confused explanations with or without the use of manipulation of irrelevant numbers of factors which were invented by the student:

   Example (Shadows Problem): "The post is 3 meters tall and the shadow is 2 meters tall. The building would be 60 meters tall."

   Example (Frog Problem): "It mattered how well he drained the pond. If he did a good job there are not many frogs over 72. If he didn't there are more than 72."

3. The student realizes that certain quantities given in the problem are subsets of other quantities within the problem _and_ has a grasp of the relationships between these two quantities. (Realization of only one relationship where two exist does not constitute a class inclusion.) Addition and/or subtraction are carried out with that class inclusion in mind. If class inclusion is employed in a mathematical solution, relevant and irrelevant asides will be ignored.

Example (Shadows Problem): "It would be 51 meters tall. The shadow is only one meter shorter than the post. The building's shadow is 50 meters long. Add one meter and it would make it 51 meters tall.

Example (Frog Problem): "115 frogs. There must be more than a hundred frogs in the pond.

4. The student indicates ratio recognition but does not show the relationship of the ratio to the rest of the problem. The student sets up a ratio (or indicates one) and then stops.

   Example (Shadows Problem): "The ratio of 3:2 of the post."

   Example (Frogs Problem): "72/12 = 6. One out of every 6 that he found had bands."

5. The student goes beyond simple ratio recognition. A solution may not necessarily be obtained, but it is essential for the student to go beyond simply recognizing that the problem involves a ratio. The student may apply the ratio in attempting to find a solution by any method short of a true proportion, or the student may establish a proportional relationship involving all the elements of the problem which fails because the proportional relationship is improperly established or irrationally solved.

   Example (Shadows Problem): "I figured that the post shadow was 2/3 the height. So I took 2/3 of fifty. 2/3 + 50. 16 2/3 x 2 = 33 1/3."

Example (Frogs Problem): "72/12 = 0.165. 55 x 16.5 = 907.5. Approximately 907 frogs in the pond."

6. There is proper use of a proportion, demonstrating either correct solution of the problem or use of sound logic with an incorrect solution.

   Example (Shadows Problem): "If the post is longer than its shadow then the building is going to be longer than its shadow. You had to put 3 over 2 to get a larger number than 50. 3 halves of 50 is 75 so the building is 75 meters. (post) 3 / (shadows) 2 + 50 = 75."

   Example (Frogs Problem): "He could conclude that there are roughly 330 frogs in the pond. If 1/6 of the second group were already banded then 6 times the original amount were in the pond. 12/75 = 55/x 12x = 72(55) x = 330.(

7. There is proper use of a proportion with a discussion of implications of the problem or other relevant variables. For example, statements such as "evenly distributed" or "same time of day" must be abstracted in order to apply to this category. Casual mention of problem variables with discussion

or generalization does not constitute an abstraction.

Example (Shadows Problem): "The building is 75 meters tall. If the shadows are measured at the same time of day then the sun cannot mess it up."

Example (Frogs Problem): "Within the week the banded frogs were evenly spread out. By catching in any area of the pond (of the equivalent size) of the first days venture, he found that he had caught 1/6 of the population, the first day. There are about 330 frogs in the pond."

CRITERIA FOR SCORING GERANIUMS

Separation and Control of Variables

1. Non-response.

   Example: Blank paper.

   Example: "I don't know," or "I can't do it."

2. There is reiteration of the problem, with irrelevant procedures and conclusions which are concerned with "good growth conditions." The student in this category may be more concerned with growing good geraniums than with providing experiments to determine factors important to plant growth as the problem asks. Sophisticated answers may be found in this response category, and the subject may bring in outside information which in and of itself is correct but which still does not directly deal with problem variables.

   Example: "First I'd water them just enough to keep moisture in the roots so the plants get nourishment."

   Example: "I would take all the different plants and put them in different environments. The reason is to see which environment is the best for growing geranium plants."

3. The response is a description of conditions and the activities preformed on the system using problem variables. An off-on variable supply is suggested

("I'll water some and I'll leave some without; I'll fertilize some and not others.") or the subject may supply two quantity extremes, such as "a lot" versus "a little." If three situations are supplied (for example, "none," "a little," and "a lot") this is considered to be the first genuine attempt at control and the individual is judged to belong in category #4. Some of the responses in this category are elaborate, in that they provide multiple sets of conditions, but if they go no further than "a lot of water in one pot and a little in another," they cannot move higher than this category. (One exception has been made for the student who can produce a complete combinatorial scheme yet does not qualify.)

Example: "Put water in one group; water and fertilizer in the second group; water, fertilizer and sunlight in the next one; and nothing in the last one."

Example: "Put a geranium plant in soil that is fertilized, one that has nothing but water and one with just sunlight."

Example: "Have plants with different combinations of the 3 elements and some without. (I'm too lazy to write it all out.)"

Example: "Put more fertilizer in one than the other."

4. An obvious attempt is made to control the quantity of the variables. The subject shows that problem variables need to be arranged to construct an experimental procedure that will result in the isolation of each variable from the rest of the variables, but fails to control, or the subject may provide all valid combinations without quantities. Demonstration of the complete combinatory system in terms of structure was determined sufficient to rate these individuals without quantity control higher than category #3. A student may mention that he would "use all combinations," but this is not sufficient merit for him to be placed in this category without quantification. Since fertilizer, water and sunlight are the immediate variables, a complete system should include:

   1) one plant with fertilizer and water, 2) one plant with fertilizer and sun, 3) one plant with water and sun, 4) one plant with fertilizer, water and sun.

   In relation to quantification, the student may fulfill this criterion with an answer such as, "Put one in a bright spot, another in a real dark spot, but even others in dimmer places."

5. There is valid control of at least one variable, with inclusion of what the subject did to insure control. The student may list all combinations, but this does not necessarily mean he has controlled the variables. Students in this category often attempt more than one set of experiments but fail to control in all cases, either by omission of a needed test or by failure to describe how control was maintained. However, at least one variable is in fact controlled.

    Example: "Fertilize another group of plants and don't fertilize the other. Put both groups in direct sun and water both the same."

    Example: "You could put different types of fertilizer in the pots, and then grow under the same conditions."

6. There is control of all variables. Again, as in category #5, the subject explains how the controls are achieved. A student may be classified in category #6 instead of #7 because he fails to tell which variable he is testing with which test. A statement such as, "I did these things to test the variables," does not specify which variable is being tested by which experiment.

    Example: "Do this on a different plant to each variable--next increasing fertilizer, then water."

Example: "Take 6 plants:

1. Fertilize and water two plants the same, but vary the sunlight.
2. Fertilizer and sunlight the same on two, but vary the water.
3. Water and give the same amount of sunlight to the last two, but put different kinds of fertilizer on them."

7. There is control of all variables, complete with an explanation as to why the control of each variable was necessary.

Example: "I did this to see if differing amounts of water made any difference in the growth of geraniums."

Example: "The last experiment should include plants with the same amount of water and sunlight but with different amounts of fertilizer to show the effect of fertilizer on the plant growth."

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BIOGRAPHICAL SKETCH

W. Barry Miller was born in Saint John, New runswick, Canada, in 1944. Following completion of grade chool education in Saint John, New Brunswick, he graduated rom the New Brunswick Teachers College.

He received a Bachelor of Teaching (1969), a achelor of Arts (1970) and a Master of Education Degree 1974) from the University of New Brunswick in Fredericton. e has both an elementary and secondary principal's cer-ificate.

Barry became a junior high school teacher in 1966 nd in 1971 was appointed Consultant in Junior High School rogrammes with the Department of Education in the Province f New Brunswick.

In 1976, he was appointed Coordinator of Junior igh School Education and became responsible for provincial unior high school curricula. He has authored a number of overnment documents focusing on junior high school ducation.

He has provided consultative assistance to several rovinces and states and has conducted numerous professional evelopment sessions in regard to early adolescent edu-ation. In 1976, Barry was a special session speaker at he Association for Supervision and Curriculum Development nnual Conference in Miami Beach, Florida. He was a recipient of a J. Leonard O'Brian Fellowship in 1977.

He is Canadian Coordinator for the National Middle School Association, a member of the Association for Supervision and Curriculum Development, and a member of several Subject Councils for the New Brunswick Teachers' Association.

Barry is married to Loris (nee Jonah), has two sons, Justin Barry and Chad Elliott, and resides in Fredericton, New Brunswick, Canada.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Education.

Gordon S. Lawrence, Chairman
Associate Professor of
Instructional Leadership and
Support

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Education.

Paul S. George
Associate Professor of
General Teacher Education

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Education.

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